# The Journal of Bone and Joint Surgery

*The Official Publication of*
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
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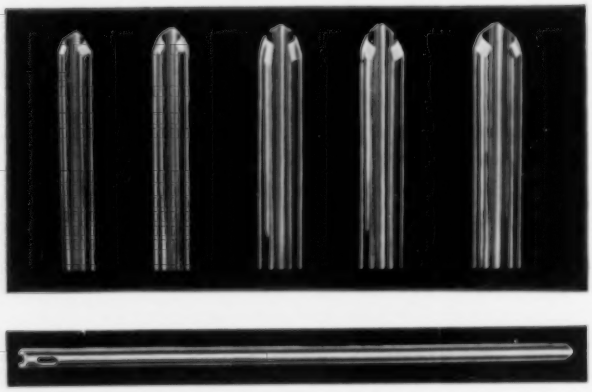

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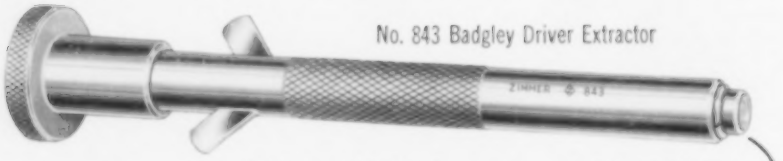


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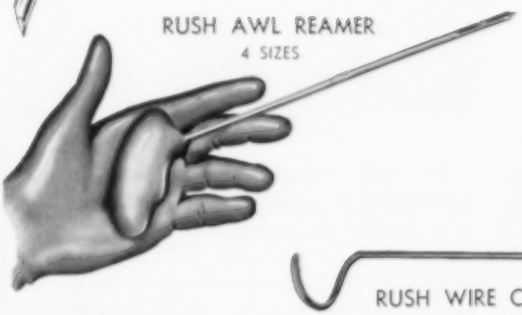

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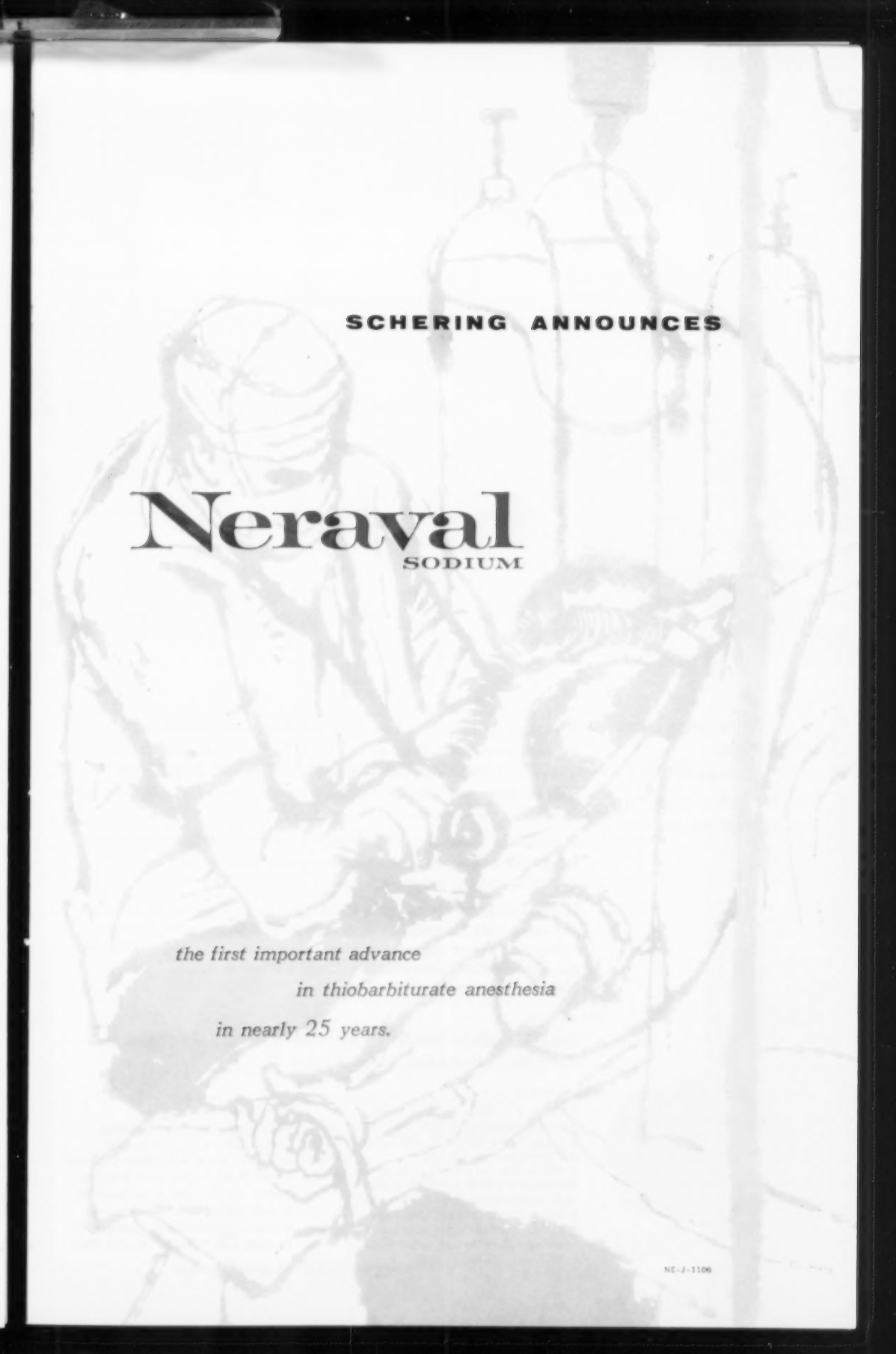

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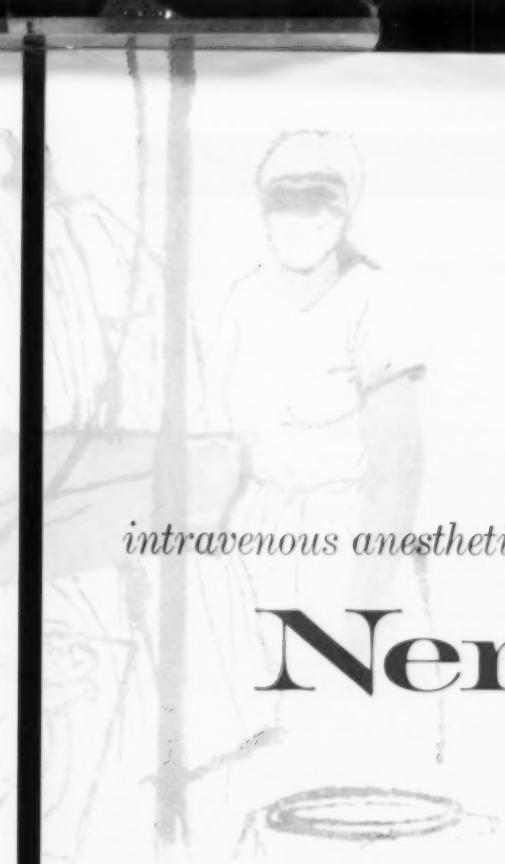

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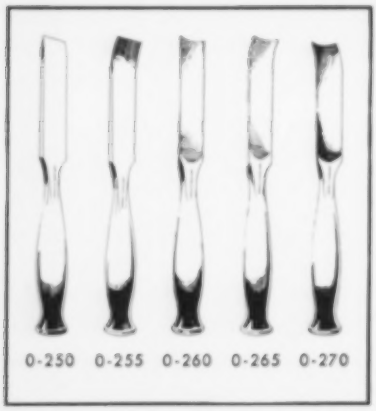

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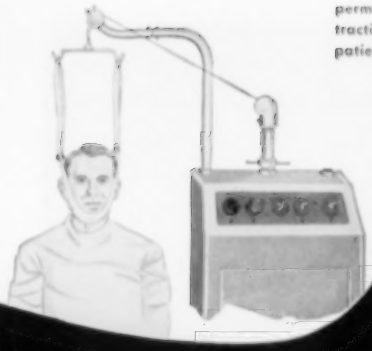

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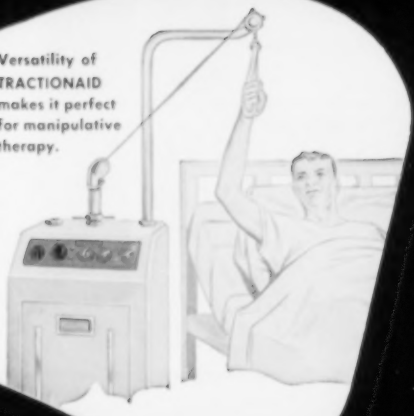

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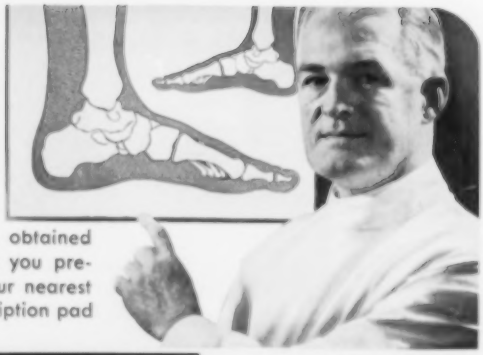

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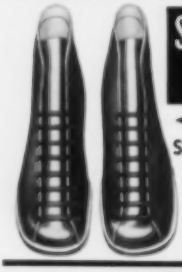

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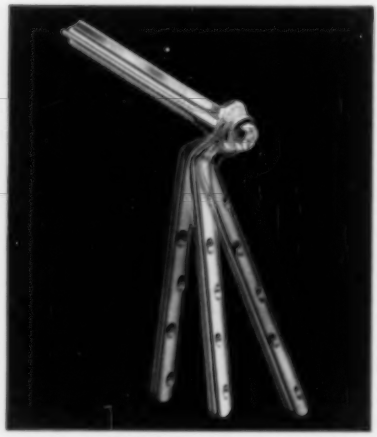

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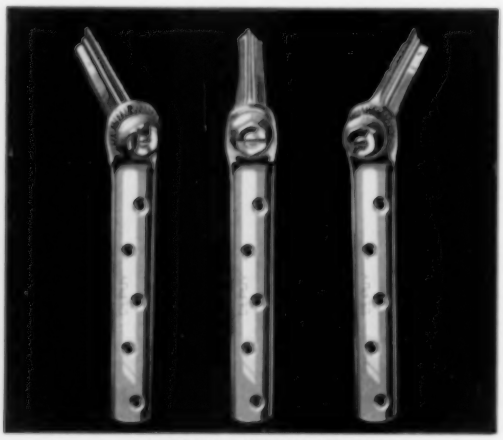

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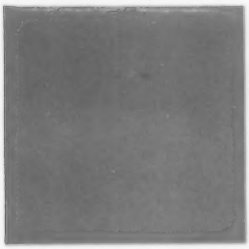

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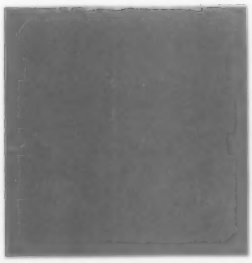

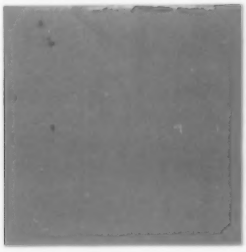

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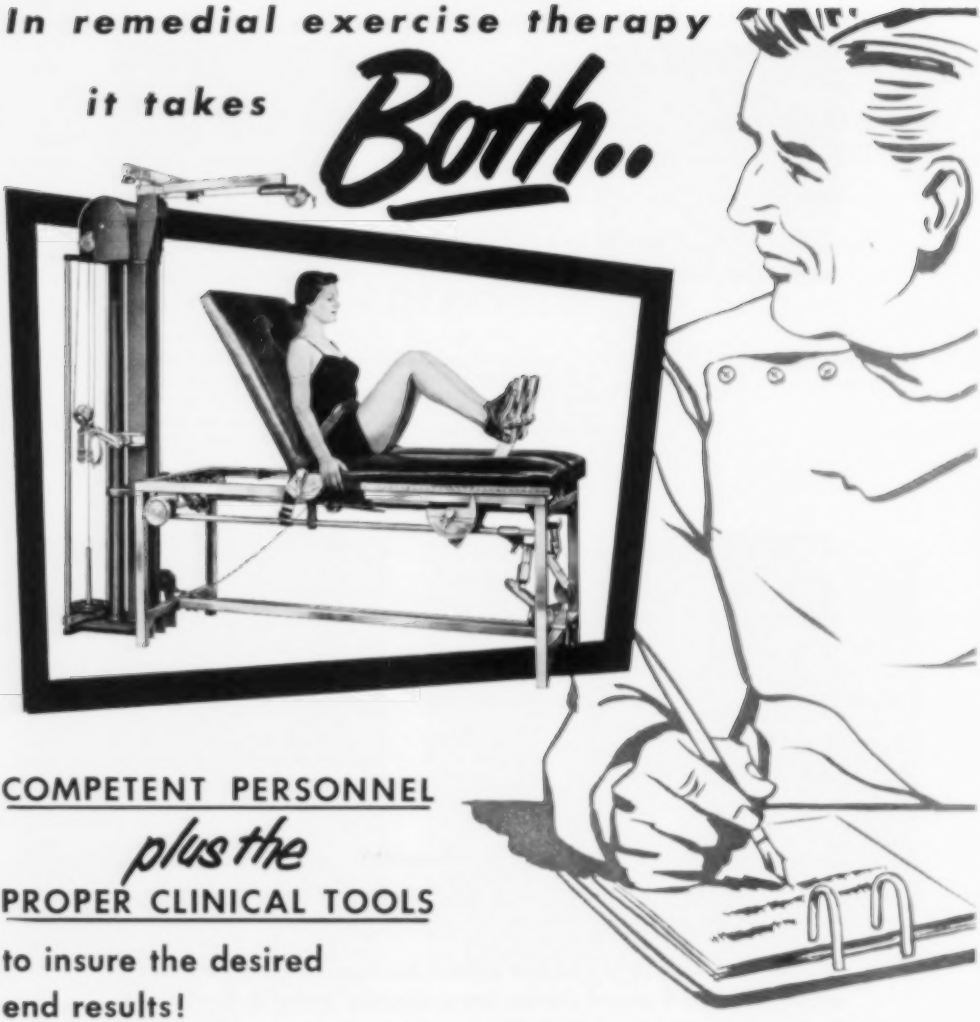

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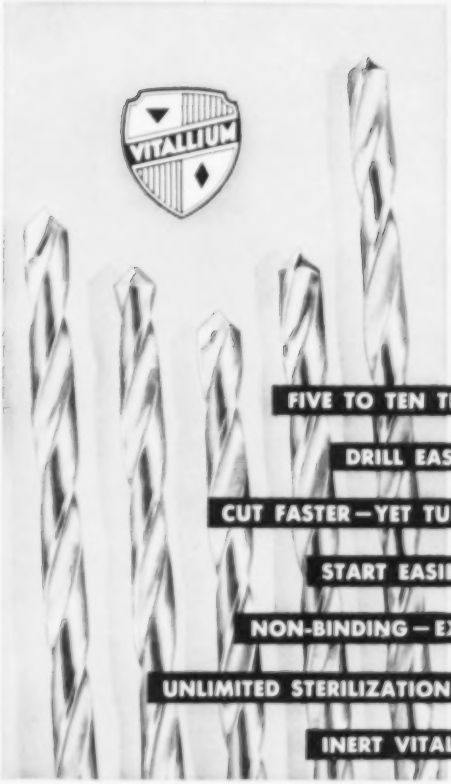


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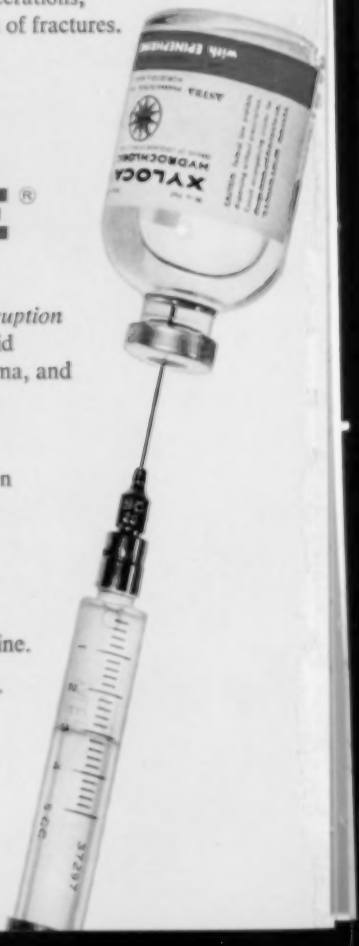


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*Southworth, J. L., and Dabbs, C. H.: Xylocaine: a superior agent for conduction anesthesia, Anesth. & Analg. *32*:159 (May-June) 1953.

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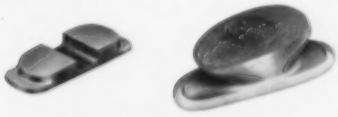

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(1) Smith, R. T.; Kron, K. N.; Peak, W. F., and Hermann, I. F.: J.A.M.A. 160:745 (Mar. 3) 1956. (2) Amols, W.: J.A.M.A. 160:742 (Mar. 3) 1956. (3) Abrahamsen, E. H., and Baird, H. W., III: J.A.M.A. 160:749 (Mar. 3) 1956. (4) Rodriguez-Gomez, M.; Valdes-Rodriguez, A., and Drew, A. L.: J.A.M.A. 160:752 (Mar. 3) 1956.

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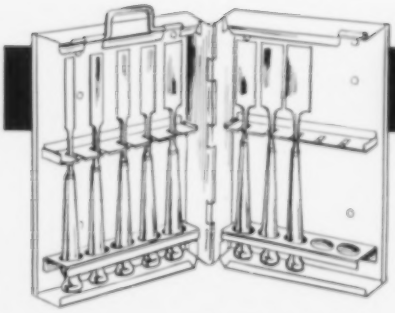

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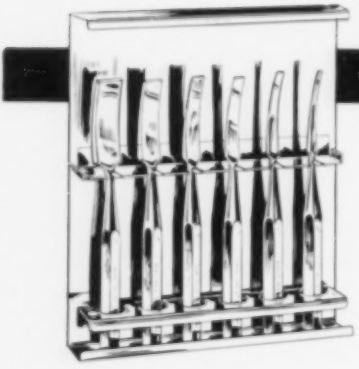

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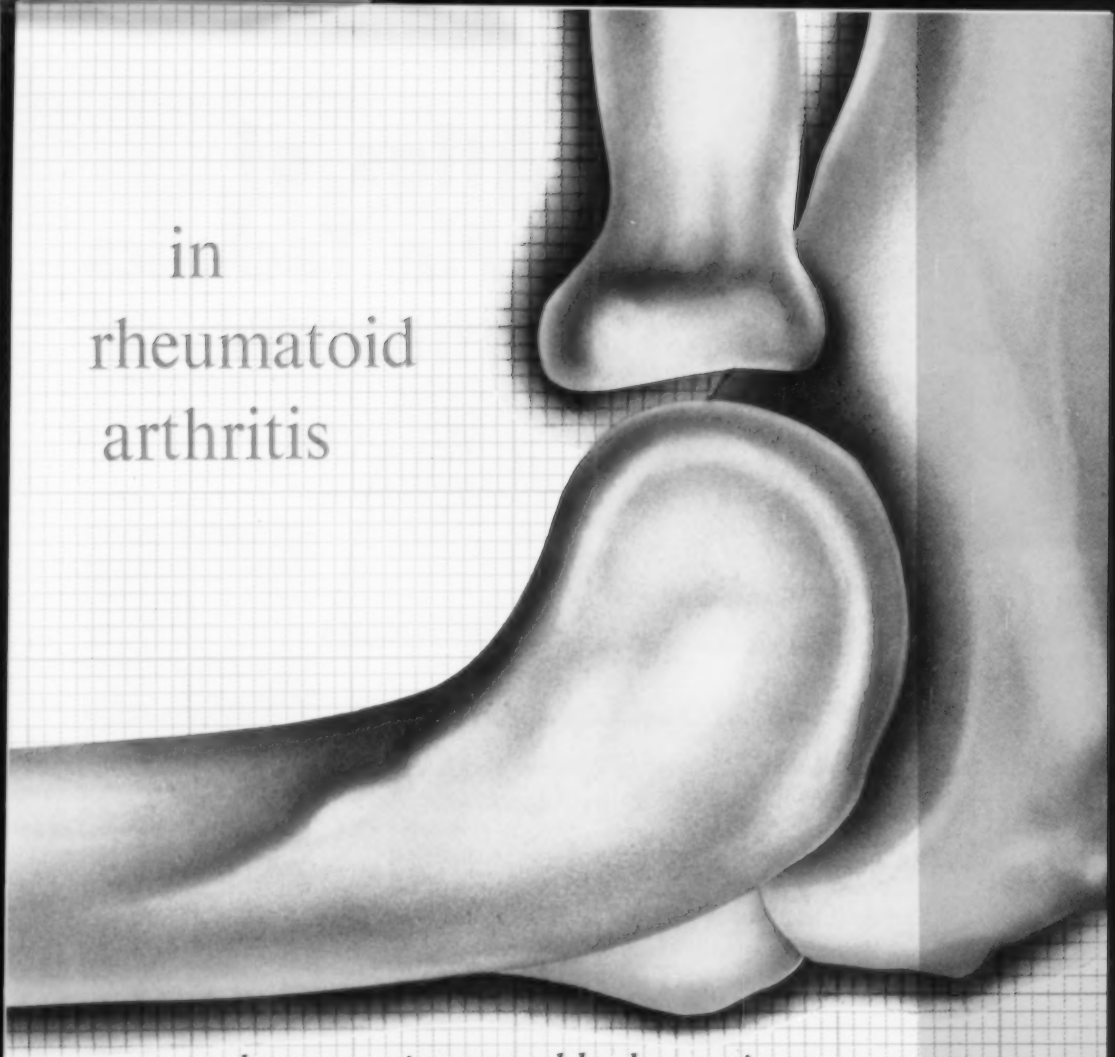

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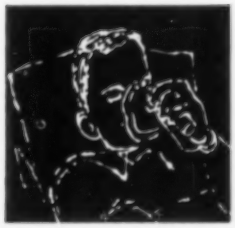

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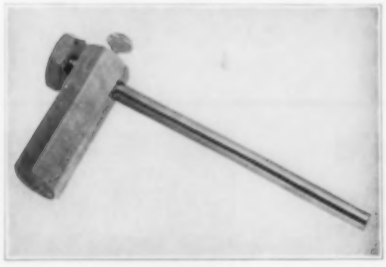

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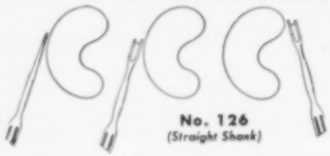

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*References:* 1. Boland, E. W., *J.A.M.A.* **160**:613 (February 25) 1956. 2. Margolis, H. M. *et al.*, *J.A.M.A.* **158**:454 (June 11) 1955. 3. Bollet, A. J. *et al.*, *J.A.M.A.* **158**:459 (June 11) 1955.

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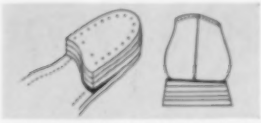

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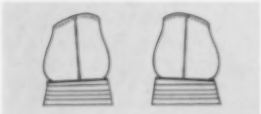

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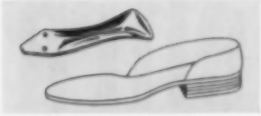

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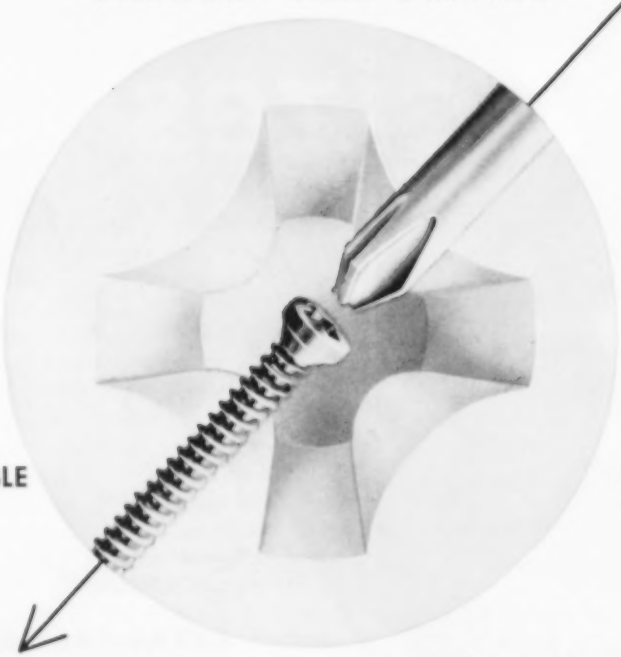

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VOL. 38-A, NO. 6 DECEMBER 1956

The Journal of
Bone and Joint Surgery
*American Volume*

# Upper-Extremity Amputation Surgery and Prosthetic Prescription *

BY ROBERT MAZET, JR., M.D., CRAIG L. TAYLOR, PH.D., AND CHARLES O. BECHTOL, M.D.,
LOS ANGELES, CALIFORNIA

*From the Prosthetic Laboratory, Department of Engineering, University of California at Los Angeles; the Department of Surgery, School of Medicine, University of California at Los Angeles; and the Wadsworth General Hospital, Veterans Administration Center, Los Angeles*

During the past four years, the Prosthetic Training Center, Engineering Department, University of California, Los Angeles, has prescribed, manufactured, and field tested upper-extremity prostheses for 240 patients.

The program in which this group has been engaged commenced in 1945. It has continued under the aegis of the Advisory Committee on Artificial Limbs of the National Research Council and has been supported by the Prosthetic and Sensory Aids Service of the Veterans Administration. In cooperation with a number of other groups†, the Training Center has analyzed and classified the basic needs of the amputee, with particular emphasis on function[8]. Development of devices to fill demonstrated needs and improvement of methods of fabricating prostheses have been undertaken by several cooperating agencies[12]. As new devices and techniques have been perfected, trial by amputee use has followed naturally. During the entire period, liaison with the several interested agencies has been close, cordial, and mutually beneficial. These phases of the program are being continued.

As pertinent information accumulated, the need for its dissemination became obvious. For this reason courses of instruction in the various phases of prosthetics were instituted for prosthetists, amputee-training therapists, and surgeons from medical centers all over the country. These courses have been in session at the Prosthetic Training Center during the past eighteen months.

The cases reported in this paper include those of patients fitted during both the developmental and teaching phases of the work. In a number of these cases two or three prostheses were made at intervals of a year or more, as better devices or methods were developed. Some of the amputees were fitted with two prostheses at the same time, the apparatuses differing from one another in some essential of harnessing, type of elbow hinge, terminal or other device, so that the patient could compare the function of the different equipment.

* Read before the Orthopaedic Section of the Annual Meeting of the American College of Surgeons, November 17, 1954, Atlantic City, New Jersey. Also read at the Annual Meeting of the Western Orthopedic Association, October 15, 1954, San Francisco, California.

† In the nation-wide program the Army Prosthetic Research Laboratory, New York University, New York, N. Y., and the United States Naval Hospital, Oakland, California, are cooperating agencies.

TABLE I

| | No. of Cases |
|---|---|
| Type of Amputation: | |
| Forequarter | 2 |
| Shoulder disarticulation (anatomical) | 12 |
| Shoulder disarticulation (prosthetic) | 8 |
| Short above-the-elbow | 17 |
| Standard above-the-elbow | 65 |
| Elbow disarticulation | 9 |
| Very short below-the-elbow | 20 |
| Short below-the-elbow | 35 |
| Medium below-the-elbow | 37 |
| Long below-the-elbow | 21 |
| Wrist disarticulation | 8 |
| | 234 |
| Type of Cineplasty: | |
| Pectoral | 7 |
| Above-the-elbow biceps | 1 |
| Below-the-elbow biceps | 14 |
| Forearm flexors and extensors | 3 |
| | 25 |

The sites of the amputations are listed in Table I. Of the 240 patients reported in this paper, 171 were adult males, thirty-five were adult females, and thirty-four were children under sixteen years of age. Nineteen had bilateral amputations.

That the majority of the patients were adult males is explained by the fact that the Program's initial efforts were directed toward devising better prostheses for patients in this category. Successful fitting of men created a demand for application of the newer techniques to women and, more lately, to children. The latter have been included in the Program for about eighteen months. In cooperation with the Department of Pediatrics, University of California, Los Angeles, a children's amputation clinic is now functioning. At this clinic some of the diverse problems apposite to children are being reviewed and solved*.

For many years the standard treatises on arm-amputation surgery have emphasized the desirability of shaping the stumps within the confines of so-called "sites of election"[7,14,16,17] (Fig. 1). Amputation through other areas in both the upper and lower extremities, while not specifically forbidden, has been discouraged principally for prosthetic reasons (Fig. 2). There has been universal agreement that in the hand one should save all bone possible, except for the bulbous distal ends of the phalanges and, in certain circumstances, of the metacarpals.

A changing attitude toward the amputation site has been evident in the literature. Earlier writers, such as Kessler in 1939 and Carnes in 1941, condemned amputation in the wrist and elbow regions. In 1946, however, McKeever stated that preservation of the carpus is advantageous. He regarded wrist disarticulation unfavorably but stated that preservation of even a short forearm stump and of elbow motion is beneficial. Later articles

Fig. 1: Left: "sites of election" and areas previously considered undesirable for amputation. Right: types of upper-extremity stumps as classified by the Prosthetic Laboratory.

Fig. 2: Diagram showing (1) types of amputation, (2) reasons for previous rejection of these types, (3) devices now available for prosthetic replacement, and (4) advantages of amputation at these levels.

* The Michigan State Crippled Children's Commission is also cooperating in this work.

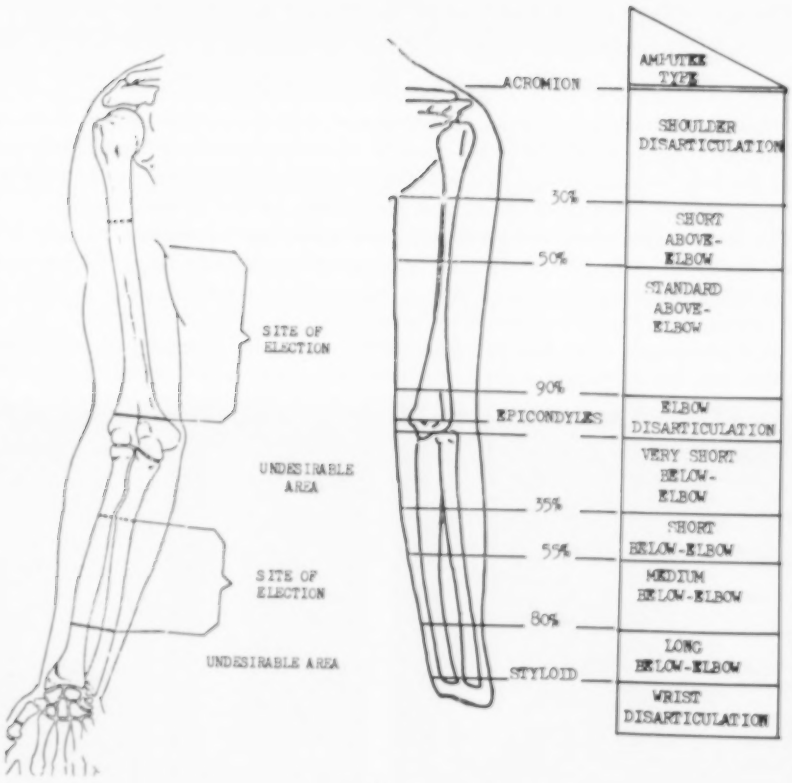

SITE OF ELECTION
UNDESIRABLE AREA
SITE OF ELECTION
UNDESIRABLE AREA
ACROMION
30%
50%
90%
EPICONDYLES
35%
55%
80%
STYLOID
AMPUTEE TYPE
SHOULDER DISARTICULATION
SHORT ABOVE-ELBOW
STANDARD ABOVE-ELBOW
ELBOW DISARTICULATION
VERY SHORT BELOW-ELBOW
SHORT BELOW-ELBOW
MEDIUM BELOW-ELBOW
LONG BELOW-ELBOW
WRIST DISARTICULATION

FIG. 1

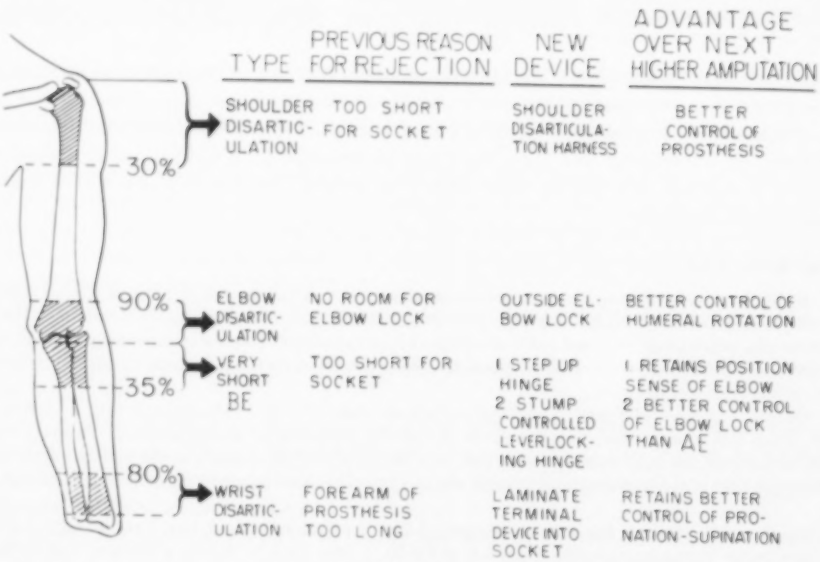

TYPE
PREVIOUS REASON FOR REJECTION
NEW DEVICE
ADVANTAGE OVER NEXT HIGHER AMPUTATION
30%
SHOULDER DISARTICULATION
TOO SHORT FOR SOCKET
SHOULDER DISARTICULATION HARNESS
BETTER CONTROL OF PROSTHESIS
90%
ELBOW DISARTICULATION
NO ROOM FOR ELBOW LOCK
OUTSIDE ELBOW LOCK
BETTER CONTROL OF HUMERAL ROTATION
35%
VERY SHORT BE
TOO SHORT FOR SOCKET
1. STEP UP HINGE
2. STUMP CONTROLLED LEVERLOCKING HINGE
1. RETAINS POSITION SENSE OF ELBOW
2. BETTER CONTROL OF ELBOW LOCK THAN AE
80%
WRIST DISARTICULATION
FOREARM OF PROSTHESIS TOO LONG
LAMINATE TERMINAL DEVICE INTO SOCKET
RETAINS BETTER CONTROL OF PRONATION-SUPINATION

FIG. 2

by Alldredge, Canty, Larmon, and Swenson and Bisgard espoused the preservation of bone in all these areas, if possible, in order to prevent the sacrifice of wrist and elbow motion.

### STUMPS OF THE CARPUS AND DISTAL END OF THE FOREARM

Transcarpal amputation, wrist disarticulation, and amputation below the junction of the middle and lower thirds of the forearm have been generally interdicted, for previously the long forearm stumps that resulted from these operations have allowed insufficient space for the insertion of the holding mechanism for the terminal device.

The distal region which is involved in these operations corresponds roughly to what we now designate as the area of the long below-the-elbow stump (Fig. 1). It has been our experience that preservation of wrist flexion (transcarpal amputation) and rotation (wrist disarticulation and long below-the-elbow amputation) is distinctly beneficial. The introduction of plastic materials and the development of a thin wrist adapter which may be laminated into the substance of the forearm socket enable us now to fabricate a forearm

FIG. 3-A

FIG. 3-B

FIG. 3-C

Fig. 3-A: Roentgenograms made following transmetacarpal amputation.
Fig. 3-B: Photograph showing vestigial stump.
Fig. 3-C: Patient wearing a wrist cuff and a voluntary-opening hook.

socket that is not longer than the opposite forearm and to preserve forearm rotation with no sacrifice of prosthetic function.

With respect to prosthetic fitting, it has been noted that if the radial and ulnar styloid processes are covered by thin skin, they may be irritated by a tightly fitting socket when the arm is rotated. We believe these should be excised. Slocum has also stated that this is sometimes desirable.

*Illustrative Cases*

R. N., a ten-year-old boy, had congenital absence of the right foot and of most of the left hand. All the carpal bones were present, along with part of the metacarpals and a nubbin of the thumb, but there were no phalanges (Figs. 3-A and 3-B). No finger function existed. There was some wrist flexion, but no extension. He could walk and run when wearing a lower-extremity prosthesis. He was classified prosthetically as a carpometacarpal amputee.

On July 7, 1953, a carpometacarpal-type prosthesis with a No. 88 Dorrance hook (Fig. 3-C) was delivered. When last seen he was using the device constantly, including at social functions. To use a baseball glove he inserted one hook finger into the thumb of the glove and the other into the middle finger. He was making good use of the flexion mechanism. He had had to have several minor repairs, the last on July 13, 1955.

On June 23, 1952, at the age of thirteen, G.C., a left-handed school boy, lost his right hand and eye in a home chemistry explosion (Figs. 4-A and 4-B). A year after the injury a neuroma was excised. He wore no prosthesis until fifteen months after the accident. During this interval the introverted boy, whose

I.Q. was 113, became much more withdrawn. He participated in no outside social activities and would join family activities only when urged. His initial prosthesis consisted of a wrist cuff with interchangeable hand and hook (Fig. 4-C). He rejected the hook almost entirely but became quite proficient in the use of the hand. Personality changes were apparent almost at once. He re-entered contemporary society and participated in school activities. He played the violin in his school orchestra. His hobby was photography, and he did his own developing and printing. There was complete acceptance of the prosthesis by family and schoolmates.

He was last seen twenty-five months after the fitting. At that time he was wearing the hand throughout all his waking hours. He had remained somewhat withdrawn but had accepted his handicap well and had been much better adjusted since he had started wearing the prosthesis.

### STUMPS OF THE PROXIMAL PORTION OF THE FOREARM

It has been generally believed in the past that the proximal third of the forearm and the distal two inches of the humerus should be sacrificed, again primarily because no adequate prostheses were available.

The proximal third of the forearm corresponds roughly to the area of the very short

FIG. 4-A

FIG. 4-B

FIG. 4-C

Fig. 4-A: Roentgenograms made following wrist disarticulation.
Fig. 4-B: Photograph showing the wrist following disarticulation amputation.
Fig. 4-C: A wrist-disarticulation prosthesis with a functional hand and cosmetic glove.

below-the-elbow stump (see classification in Figure 1). Fitting in this area has been a problem, particularly with fleshy stumps, because a socket which is snug when the elbow is extended tends to be forced distally by the soft tissues when the elbow is flexed. This not only is a source of discomfort to the patient but also limits the functional range of the prosthesis by restricting flexion.

Blair and Morris advocated release of the biceps insertion to ameliorate this difficulty. This simple procedure has proved beneficial in some of our cases. The rather commonly seen limitation of elbow motion often present in such short stumps has been another contra-indication.

Our present armamentarium includes three items which enable us to circumvent these disadvantages. The double-pivot hinge (Fig. 5) permits the socket to maintain its position on the short stump even when there is good elbow motion and when as little as two inches of the ulna remains.

If elbow motion is restricted to an extent which seriously impairs function, the stump may be fitted with a split socket and variable-ratio hinge (Fig. 6). This provides one-

and-one-half times as much motion in the forearm section of the prosthesis as there is in the stump. As the stump moves through an arc of 90 degrees, the forearm section of the artificial arm moves through an arc of 135 degrees. There is a corresponding loss of strength in elbow flexion. Since the amputee customarily uses the amputated limb as the holding rather than working appendage, he is better served by an increased range of motion at the sacrifice of some strength.

When there is a fixed flexion deformity of the elbow, an inner socket which firmly grasps the stump can be fitted in the position of the deformity, while the outer socket, to which the terminal device is attached, may be placed in 165 or 170 degrees of extension. Aitken and Frantz reported the successful use of these appliances in children.

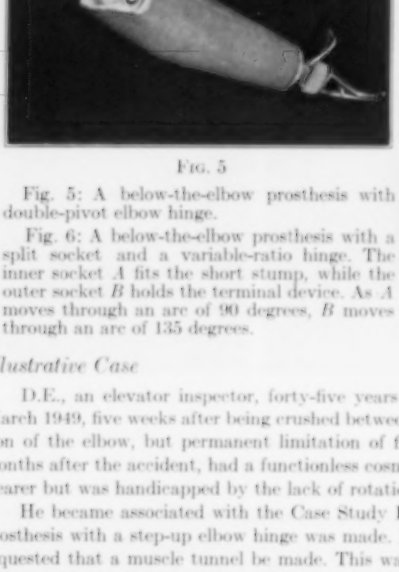


FIG. 5

Fig. 5: A below-the-elbow prosthesis with double-pivot elbow hinge.

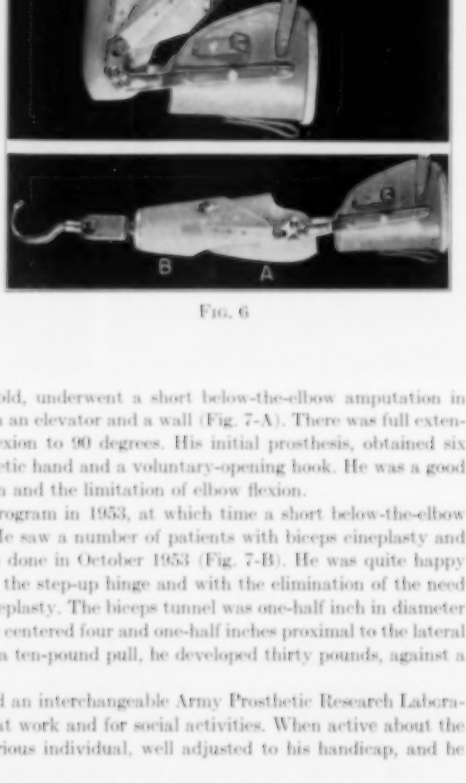



FIG. 6

Fig. 6: A below-the-elbow prosthesis with a split socket and a variable-ratio hinge. The inner socket *A* fits the short stump, while the outer socket *B* holds the terminal device. As *A* moves through an arc of 90 degrees, *B* moves through an arc of 135 degrees.

*Illustrative Case*

D.E., an elevator inspector, forty-five years old, underwent a short below-the-elbow amputation in March 1949, five weeks after being crushed between an elevator and a wall (Fig. 7-A). There was full extension of the elbow, but permanent limitation of flexion to 90 degrees. His initial prosthesis, obtained six months after the accident, had a functionless cosmetic hand and a voluntary-opening hook. He was a good wearer but was handicapped by the lack of rotation and the limitation of elbow flexion.

He became associated with the Case Study Program in 1953, at which time a short below-the-elbow prosthesis with a step-up elbow hinge was made. He saw a number of patients with biceps cineplasty and requested that a muscle tunnel be made. This was done in October 1953 (Fig. 7-B). He was quite happy with the 135 degrees of elbow motion provided by the step-up hinge and with the elimination of the need for an opposite-shoulder loop resulting from the cineplasty. The biceps tunnel was one-half inch in diameter and one and three-quarters inches in length and was centered four and one-half inches proximal to the lateral epicondyle. The excursion was two inches. Against a ten-pound pull, he developed thirty pounds, against a one-pound pull, twenty-four pounds.

The prosthesis he was using when last seen had an interchangeable Army Prosthetic Research Laboratory hand and hook (Fig. 7-C). He wore the hand at work and for social activities. When active about the house, he wore the hook. He was a stable, industrious individual, well adjusted to his handicap, and he obtained excellent function from the prosthesis.

If the stump is exceptionally short, so that its strength is insufficient to support any useful load, the patient can be provided with an above-the-elbow type of control. With this, elbow flexion and terminal-device function are activated by a shoulder harness (Fig. 8). The stump often satisfactorily stabilizes the elbow, and it may be used to activate the outside-locking elbow hinge.

FIG. 7-A

FIG. 7-B

FIG. 7-C

Fig. 7-A: Roentgenograms of short below-the-elbow stump.

Fig. 7-B: Photograph showing the stump and the pin in the biceps muscle tunnel.

Fig. 7-C: A double-socket below-the-elbow prosthesis with a variable-ratio hinge and a cineplasty terminal-device control. The flexion of the outer socket is greater than that of the inner socket on the stump.

### ELBOW DISARTICULATION

Disarticulation through the elbow joint has had several advocates in recent years, as noted above. The principal objections to this procedure have been the difficulty of fitting a prosthesis over the flaring condyles and, in cases in which the standard elbow unit has been selected, the necessity of fabricating a longer arm and a shorter forearm than is found on the normal side.

The recently perfected outside-locking elbow hinge (Fig. 9) affords good functional control of this joint. Incorporated in this is an alternating lock, similar to that of the standard humeral-activated elbow lock in general use. Because of the necessity of preserving the full load strength of this device, the number of locking positions is only five (175 degrees, 145 degrees, 115 degrees, 85 degrees, 55 degrees), as compared with the eleven positions of the standard elbow unit. New fabrication and fitting techniques make possible comfortable fitting of arm sections which are not longer than the normal arm. With these, control of arm rotation is considerably better than it is with the standard above-the-elbow artificial arm.

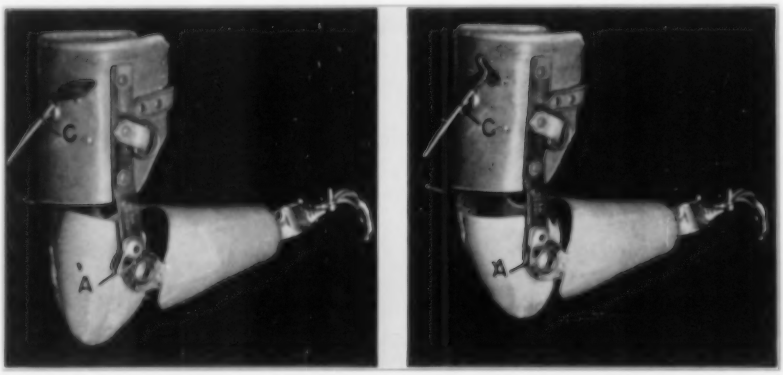



FIG. 8

A very short below-the-elbow prosthesis with a split socket. Activation of the terminal device and flexion of the elbow are obtained by means of an above-the-elbow type of control cable (*C*). The stump-activated, outside-locking elbow hinge (*A*) is shown on the left with the lock open and on the right with the lock closed.

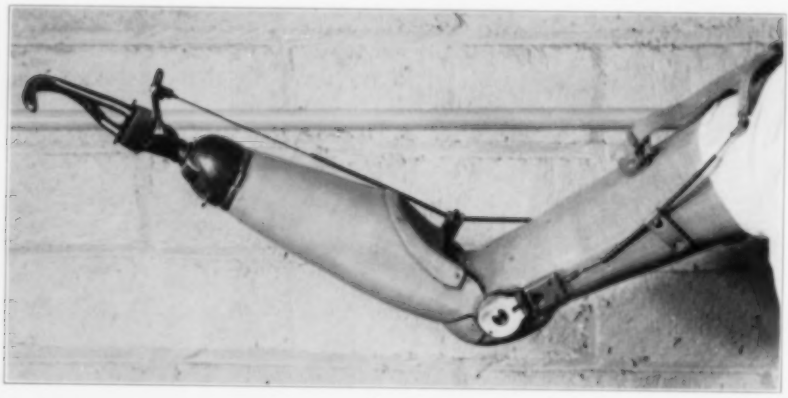


FIG. 9

An elbow-disarticulation prosthesis with an outside-locking elbow hinge. (The hinge is placed on the medial side, where it is less subject to trauma and offers less friction to clothes.)

*Illustrative Case*

G. J., forty-seven years old, was a worker in aircraft production planning. An automobile accident seven years previously had resulted in immediate left-elbow disarticulation. There had been a little sloughing of the wound, but it had healed in two months and had remained healed (Figs. 10-A and 10-B). There had been occasional phantom sensation but no phantom pain.

He had obtained his initial prosthesis three or four months following the operation. This was a steel and leather socket with a manual elbow lock and a No. 5 Dorrance lock. The patient was considerably inconvenienced because he could not carry things in the good hand and operate the elbow lock at the same time.

An examination revealed that the position of the arm in maximum abduction on flexion was about 10 degrees short of the horizontal. Shoulder rotation was normal. Most of the biceps muscle was missing, having been destroyed at the time of the accident. There was no tenderness in the stump, and the condyles had been preserved. The length of the humerus was fourteen and one-half inches.

He entered the Case Study Program in 1951 and had several prostheses built at the laboratory. He was a good wearer and obtained excellent function. When last seen he was wearing a standard elbow-disarticulation prosthesis with an outside-locking elbow joint, manual wrist rotation, and a two-load hook (Fig. 10-C). He preferred the latter because of its gradual prehension force, although it was not the most efficient for him. He appreciated the control of rotation which the presence of the humeral condyles afforded.

FIG. 10-A

FIG. 10-B

FIG. 10-C

Fig. 10-A: Roentgenograms made following elbow disarticulation. The femoral condyles have been preserved.

Fig. 10-B: Photograph of stump.

Fig. 10-C: Patient wearing an elbow-disarticulation prosthesis with an outside-locking elbow joint and a Northrop two-load hook. The socket is the same length as the opposite arm.

### SHORT ABOVE-THE-ELBOW STUMPS

The range of function of every above-the-elbow prosthesis is directly proportional to the length, strength, and range of motion of the humeral lever. It is, therefore, desirable to preserve as much of the humerus as possible. Until recently, any stump in which there was less than two inches of humerus distal to the axillary fold has been regarded as valueless for performance. It has been demonstrated, however, that even the short above-the-elbow stump (Fig. 1) has an appreciable range of function if well fitted and harnessed. In these cases a higher placement of the control-cable attachment point is obligatory in order that the activating leverage of the stump may match the load leverage of the prosthesis (Figs. 11-A and 11-B). If this is not done, the leverage power of the short humerus is insufficient to flex the prosthesis, and an angular displacement of the prosthesis on the stump results, with reduction in both function and strength. If the Campbell modulus*

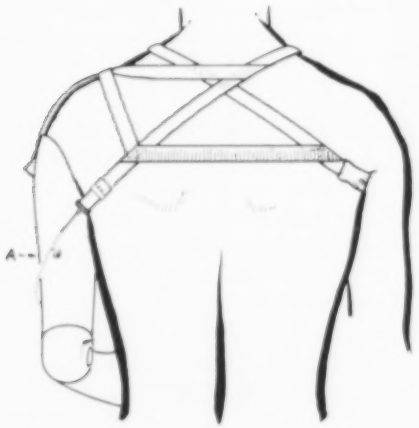



FIG. 11-A

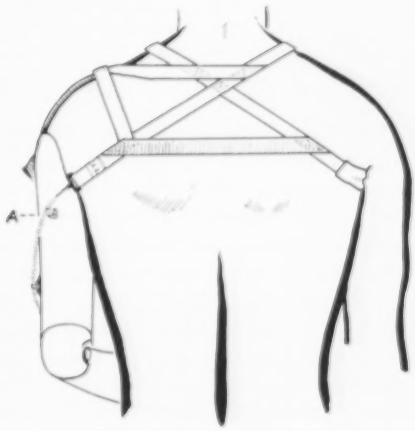



FIG. 11-B

Figs. 11-A and 11-B: Posterior views of harness for the above-the-elbow prosthesis.

Fig. 11-A: Standard placement of control-cable attachment (*A*).

Fig. 11-B: The control-cable attachment is placed higher when the above-the-elbow stump is short; the socket is also brought higher.

has not been maintained, partial reflection of the insertion of the pectoralis major [11] may result in a comparative increase in the length of the stump, which will considerably increase its range of function and its strength.

*Illustrative Case*

M. C., thirty-seven years old, a dentist and the mother of two children, was badly burned by a 12,000-volt current in June 1941. Bilateral above-the-elbow amputations resulted. On the right side the length of the remaining portion of the humerus was five and three-quarters inches (Figs. 12-A and 12-B). On the left, only the humeral head was retained. She wore no prosthetic device on the shorter limb and wore an artificial arm with little function on the right. She entered the Case Study Program in 1953. A standard short above-the-elbow prosthesis was fabricated for the right limb.

The active motion possible with the prosthesis was 65 degrees of flexion and 90 degrees of abduction. She could cook, take care of her home and children, and drive her car. She also could use a glass and cup. In 1955, she received a Northrop Sierre model-A wrist-flexion unit (with a control plunger operated by being struck against an object such as the table) which considerably enhanced the prosthetic function (Fig. 12-C).

* The ratio of the length of the humerus beyond the axilla to the diameter of the arm at the axilla, as it appears on the anteroposterior roentgenogram, should be 1.33 (or more) to 1 if good function is to be obtained.

FIG. 12-A

FIG. 12-B

FIG. 12-C

Fig. 12-A: Roentgenogram of short humeral stump.
Fig. 12-B: Photograph of stump.
Fig. 12-C: Patient wearing a standard short above-the-elbow prosthesis.

## SHOULDER DISARTICULATION

Retention of the head of the humerus, when a high amputation is necessary, has long been advocated for cosmetic reasons. Its presence is also extremely valuable for prosthetic reasons. With the humeral head in the glenoid, the shoulder cap of the disarticulation prosthesis has a much securer grip and its tendency to slide around the shoulder is definitely minimized. The prosthesis, therefore, follows shoulder-girdle motion better, with the result that the patient has better function than he would with the less stable shoulder cap, which is necessary when the humeral head is absent. Utilizing the cross-chest or the modified figure-of-eight harness, either of which is less cumbersome than some of the older types of harnessing, the patient may obtain a comfortable, well fitting artificial appendage with moderately good function. The presence of the humeral head is not essential for prosthetic function.

*Illustrative Case*

O. V., a left-handed bakery-wagon driver, twenty-four years old, entered the hospital on March 22, 1951, because of pain and tenderness in the right shoulder. Roentgenograms revealed a lytic lesion in the upper portion of the humerus (Fig. 13-A). Biopsy disclosed a Ewing's sarcoma. On April 27, 1951, disarticulation of the right shoulder was done (Fig. 13-B).

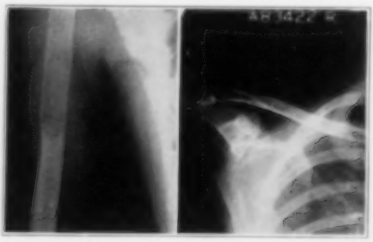


FIG. 13-A

Fig. 13-A: Left: pre-amputation roentgenogram showing lytic lesion in the humerus. Right: postoperative roentgenogram showing shoulder disarticulation.
Fig. 13-B: Photograph showing postoperative scar.
Fig. 13-C: Patient wearing a standard shoulder-disarticulation prosthesis.

FIG. 13-B

FIG. 13-C

On December 20, 1951, he was fitted with a sectional shoulder-disarticulation prosthesis, nudge-controlled elbow lock, wrist-flexion unit, and No. 55 Dorrance voluntary-opening hook. On June 11, 1952, a new type of turn-table prosthesis with a two-load hook was substituted (Fig. 13-C). He became an office worker and obtained excellent results within the limitations of the device. On April 27, 1955, roentgenograms revealed a large mass in the right thorax. This mass lay between the middle and lower lobes of the lung (Fig. 13-D). It was excised on May 16, 1955, but several small nodes were found in the lung parenchyma.

When seen on September 22, 1955, he had no complaints and was working, but roentgenograms revealed two additional nodules in the chest. At this time he used the prosthesis for carrying many objects, including suitcases, and for doing work in his home workshop; he found it helpful as an arm rest when holding his daughter, and he also used it to open doors and to type.

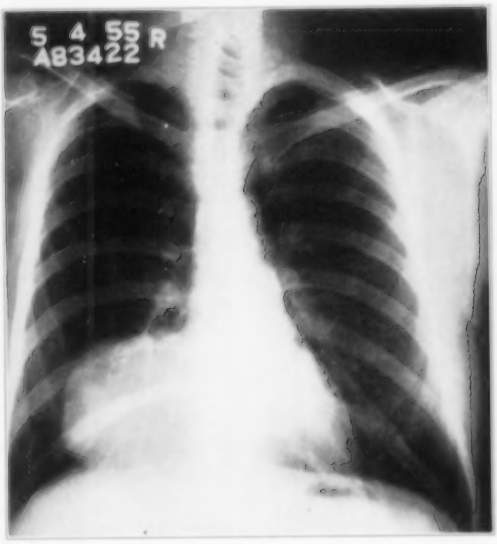



FIG. 13-D

Roentgenogram showing metastatic lesion in the right chest.

### THORACOSCAPULAR AMPUTATION

Thoracoscapular amputation is occasionally necessary. The resulting crippling effect and disfigurement can be alleviated by a prosthesis which is constructed to restore body symmetry and to provide limited function. The double-socket shoulder cap must enclose a considerable portion of the thorax in order for stability to be attained. This, and the lack of shoulder-girdle motion, limit prosthetic function considerably. However, elbow flexion and prehension are obtainable. A good cosmetic result may also be achieved.

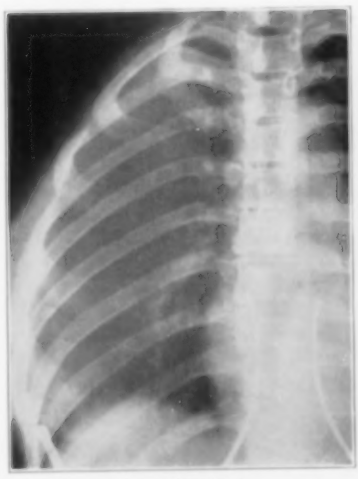


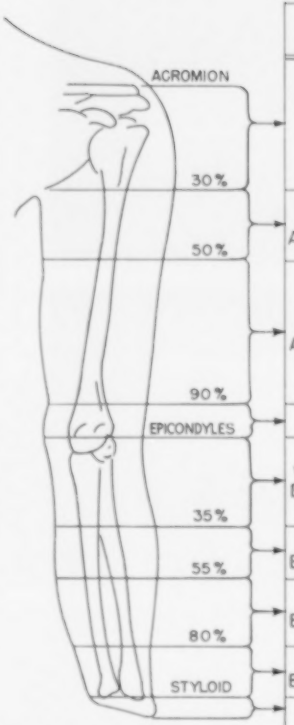
FIG. 14-A

FIG. 14-B

FIG. 14-C

Fig. 14-A: Roentgenogram of the thorax showing the absence of a shoulder girdle.
Fig. 14-B: Photograph showing asymmetry of the trunk.
Fig. 14-C: Patient wearing the prosthesis. The necessity for a large shoulder cap is evident.

## AMPUTEE TYPES AND SUGGESTED ARMAMENTARIUM




| AMPUTEE TYPE | TERMINAL DEVICE | WRIST DEVICE | FOREARM COMPONENT | ELBOW DEVICE | ARM COMPONENT | HARNESS TYPE | CONTROL TYPE |
|---|---|---|---|---|---|---|---|
| SHOULDER DISARTIC-ULATION | APRL HAND, or HOOK | 1. DISCONNECT 2. FLEXION * | STANDARD SHELL | ACTIVE LOCKING | SHOULDER SOCKET | CHEST STRAP or FIG. 8 | DUAL + |
| SHORT ABOVE-ELBOW | APRL HAND, or HOOK | 1. DISCONNECT 2. FLEXION * | STANDARD SHELL | ACTIVE LOCKING | SINGLE or DOUBLE SOCKET | AE FIG. 8 | DUAL |
| STANDARD ABOVE-ELBOW | APRL HAND, or HOOK | 1. DISCONNECT 2. FLEXION * | STANDARD SHELL | ACTIVE LOCKING | SINGLE or DOUBLE SOCKET | AE FIG. 8 | DUAL |
| ELBOW DISARTIC. | APRL HAND, or HOOK | 1. DISCONNECT 2. FLEXION * | STANDARD SHELL | OUTSIDE LOCKING | SINGLE SOCKET | AE FIG. 8 | DUAL |
| VERY SHORT BELOW-ELBOW | APRL HAND, or HOOK | 1. DISCONNECT 2. FLEXION * | SPLIT SOCKET | OUTSIDE LOCKING or STEP-UP | HALF or FULL CUFF | BE FIG. 8 | SINGLE or DUAL |
| SHORT BELOW-ELBOW | APRL HAND, or HOOK | 1. DISCONNECT 2. FLEXION * | DOUBLE SOCKET | INSERT or METAL | HALF or FULL CUFF | BE FIG. 8 | SINGLE |
| MEDIUM BELOW-ELBOW | APRL HAND, or HOOK | 1. DISCONNECT 2. FLEXION * 3. ROTATION * | SGL, DBL, or ROTATION SOCKET | INSERT, METAL or FLEXIBLE | HALF or FULL CUFF | BE FIG. 8 | SINGLE |
| LONG BELOW-ELBOW | APRL HAND, or HOOK | 1. DISCONNECT 2. FLEXION * 3. ROTATION * | SGL, DBL, or ROTATION SOCKET | INSERT, METAL or FLEXIBLE | HALF or FULL CUFF, or TRI-CEPS PAD | BE FIG. 8 | SINGLE |
| WRIST DISARTIC. | APRL HAND, or HOOK | DISCONNECT OR NONE ‡ | SGL. or DBL. SOCKET | FLEXIBLE | TRICEPS PAD | BE FIG. 8 | SINGLE |

* —— IF INDICATED.

‡ —— TERMINAL DEVICE MAY BE LAMINATED INTO SOCKET.

\+ —— NUDGE, LANYARD, OR AXILLA LOOP FOR ELBOW LOCK CONTROL.

TEACHING NOTE NO. 11
PROSTHETICS TRNG. CTR.
UCLA —— MAY 1953

Fig. 15

*Illustrative Case*

P. H., a thirty-year-old housewife, was seen in September 1954, because of a mass in the right biceps region. Biopsy revealed a rhabdomyosarcoma, and in January 1955, a thoracoscapular amputation was performed (Figs. 14-A and 14-B). In June 1955, a laminated plastic prosthesis with an Army Prosthetic Research Laboratory hand and voluntary-opening hook was fitted. When last seen, she had worn the prosthesis for four months but unfortunately had learned to make little use of the voluntary-opening hook within the arc of forearm motion. The inherent lack of shoulder and shoulder-girdle motion on the injured side in patients with this type of amputation is, of course, a considerable handicap to prosthetic function.

## CONCLUSIONS

Inasmuch as a number of persons with amputations in the so-called undesirable areas have been successfully fitted with appliances developed in recent years, it is our contention that the concept of "sites of election" in upper-extremity amputations is obsolete. Amputation surgery of the upper extremity should be directed toward saving all possible length in all areas. Prosthetic considerations need not dictate the amputation site. Physical aspects, such as skin coverage, adequacy of circulation, good innervation, and function of the part to be saved, should be the determining factors in the decision as to the level of amputation.

Familiarity with the latest techniques of prosthetic manufacture and fitting are as essential for the surgeon as his knowledge of surgical techniques. Realization of the potentialities and limitations of recently developed prosthetic appurtenances are necessary for the prescription of the appliance best suited to the needs of the individual. Functional prosthetic replacements are available for almost all types of upper-extremity amputations[10] (Fig. 15). Prescription of the prosthesis which is best suited to the individual requirements of the patient is the privilege of the surgeon. This cannot be delegated.

The surgeon should share the responsibility for amputee rehabilitation with the other members of the prosthetic team (the patient, therapist, trainer, prosthetist, job counselor, and psychologist), but he must remain captain. His responsibility to the patient does not terminate with wound healing. It continues through the period of rehabilitation. He must, with cooperation from other team members, supervise the readjustment of the patient to his handicap and direct the restoration of the patient to social and economic independence.

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# Perilunar Dislocations *

BY CARRUTH J. WAGNER, M.D., SAN FRANCISCO, CALIFORNIA

Dislocations of the carpus occur commonly enough to warrant the attention of the surgeon who is interested in the hand. Difficulties in treatment arise from the diverse and confusing classification of these injuries [1, 2, 3, 4] and from the lack of any clearly defined criteria on which to base the treatment and the prognosis of the individual case. Although most carpal dislocations occur as a result of a fall on the outstretched hand, the exact mechanism of injury can seldom be determined. Furthermore, the dislocation may be partially or completely reduced by self manipulation before the patient is seen by the physician and roentgenologist, and consequently may be underdiagnosed. Finally, because of the intricate relationships of the various components of the carpus to the function of the wrist as a whole [1, 5], the numerous manifestations of the injury cannot be considered in terms of one bone or one joint.

This report is based upon a clinical study of seventy-eight carpal injuries in which there were varying degrees of loss of the normal relationship between the lunate and capitate. These injuries have been classified under the general term, *perilunar dislocation*, and an attempt has been made to correlate them from the clinical viewpoint of treatment and prognosis.

Anatomically, the carpus is composed of eight carpal bones arranged in a proximal and a distal row. Functionally, the lunate and the triangular with the pisiform act as a unit in the proximal row, and the lesser multangular, the capitate, and the hamate act as a unit in the distal row. The navicular functions as a connecting rod between the two rows, and the greater multangular functions as a modified metacarpal.

Normally, most of the volar flexion of the hand takes place in the radiocarpal joint and to a lesser extent in the mid-carpal joint. Dorsal flexion is primarily a function of the mid-carpal joint, the radiocarpal joint contributing only slightly to the movement. Radial deviation of the hand is essentially a function of the mid-carpal joint and ulnar flexion is mainly radiocarpal in origin.

The function of the radiocarpal joint is relatively simple as an ellipsoidal joint,

* Read at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 27, 1956.

but the mid-carpal joint is more complex since it functions differently on the radial and the ulnar sides of the mid-axial line. The radial portion of the mid-carpal joint is represented by the distal half of the navicular, the greater and the lesser multanguli rotating about the radial aspect of the capitate; there is a slight gliding movement in the lateral and the medial portions of the joint.

The ulnar portion of the mid-carpal joint, consisting of the lunate, the proximal pole of the navicular, the hamate, and the triangular, acts as a multi-axial diarthrodial joint about the distal ulnar surface of the capitate.

The capitate is firmly fixed to the third metacarpal, through which progresses the long axis of the hand into the carpus. The ligamentous attachments of the various carpal bones are so arranged that the lesser multangular, the distal pole of the navicular, the

FIG. 1

Dorsal dislocation of carpus.

capitate, hamate, and triangular form a close-knit group firmly attached to the metacarpals, while the lunate and the proximal pole of the navicular represent a separate element in contact with the radius. When a force is applied to the dorsiflexed wrist which exceeds the range of motion naturally permitted by the various ligaments, the lunate is usually buttressed by the dorsal lip of the radius and clings to the proximal pole of the navicular. The distal pole is carried dorsally by the rest of the carpus and a fracture of the wrist of the navicular usually results.

If, however, the dorsal lip of the radius gives way, if the volar inclination of the radius is not present, or if the force is applied perpendicular to the hand, the entire carpus dislocates dorsally (Fig. 1). Although the carpus continues to function as a unit and the lunate-capitate joint appears normal, a disturbed relationship exists between the lunate and the triangular on one side and the navicular on the other. This occurs rarely, and seems to indicate that the distribution of the various ligaments binding the carpal bones to each other and to the radius permits independent motion of the individual joints, and at the same time enables the carpus to act as a unit. It is this paradox of function of the ligamentous structures of the carpus which makes possible a wide variety of frac-

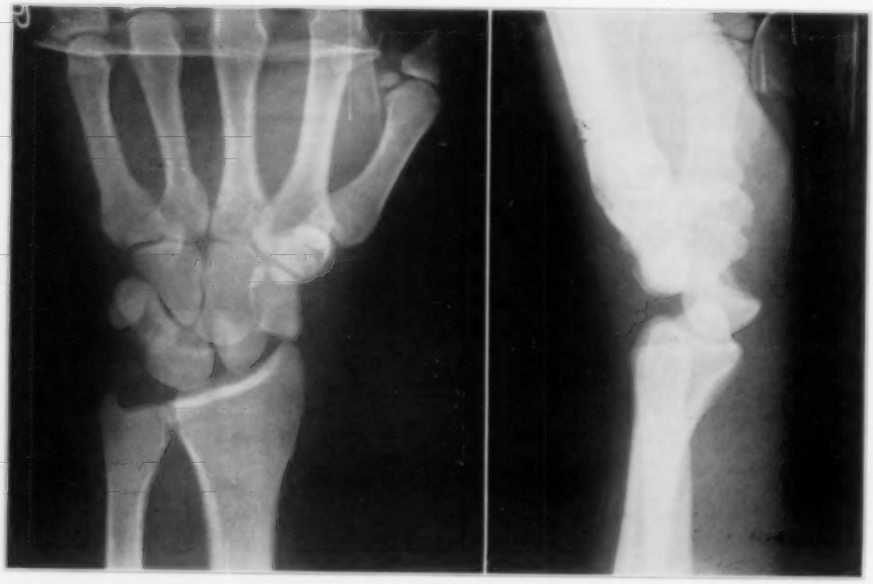

FIG. 2

Typical perilunar transnavicular dislocation showing relationship of the lunate and the proximal navicular fragment.

ture-dislocations of the carpus, at the same time placing all types of dislocations on a sequential basis.

When the navicular is fractured the fragments do not displace if the force is dis-

FIG. 3-A

FIG. 3-B

Fig. 3-A: Perilunar dislocation without fracture of the navicular accompanied by a fracture of the radial styloid process which allows the proximal pole of the navicular to escape.

Fig. 3-B: Lateral roentgenogram showing perilunar dislocation without fracture of the navicular.

FIG. 4

FIG. 5

Fig. 4: Occasionally a small flake of the navicular remains with the lunate.

Fig. 5: If the disrupting force continues, the capitate migrates to the level of the radial articular surface and the tilt of the lunate is toward the volar surface.

sipated. The anatomical relationship of the fractured portion of the carpus to the rest of the hand is often maintained so well that the articular cartilage remains intact across the fracture site. If, however, the force continues, the navicular fragments separate and the proximal pole remains with the lunate, while the distal fragment accompanies the capitate and the rest of the carpus dorsally in the typical perilunar dislocation (Fig. 2). The capitate, the hamate, the triangular, the lesser multangular, and the distal fragment of the navicular remain in normal relationship to each other, while the lunate, together with the proximal fragment of the navicular, maintain normal relationship to the radius.

If the navicular dislocates but fails to fracture, it must sever its relationship with the lunate and accompany the capitate or remain behind with the lunate. Since its connections with the capitate and the multanguli are the stronger of the two relationships, the former is what usually happens. The radial styloid process frequently fractures to allow the escape of the proximal fragment of the navicular (Figs. 3-A and 3-B). Variations in the direction of the force will result in avulsion of the ulnar styloid process and occasionally a small fragment of the navicular is left behind (Figs. 4 and 5).

If the force continues after the dislocation of the capitate-lunate joint, the carpus usually by-passes the lunate and may be pushed proximally to the level of the articular surface of the radius (Figs. 3-A, 3-B, 4, and 5). If, however, excessive dorsiflexion occurs, the lunate may be "popped out of its radial seat like a pumpkin seed" [1] resulting in a volar dislocation of the lunate (Fig. 6). The capitate with its entourage may then assume a relatively normal relationship to the radius (Fig. 6) and on examination it may appear that a simple dislocation of the lunate has taken place. The fact that the lunate dislocation was preceded by a perilunar dislocation can be demonstrated at the time of reduction. When the wrist is brought into dorsiflexion the carpus can be felt to dislocate dorsally, after which the lunate slips easily into its radial berth. With traction and palmar flexion the perilunar dislocation may then be reduced.

FIG. 6

Dislocation of the lunate will occur if the disrupting force continues, and the carpus resumes a relatively normal relationship with the radius.

Occasionally, the capitate will be directed more in the axis of the radius and the lunate, and the proximal pole of the navicular will dislocate dorsally. Usually, the lunate fractures and only a portion of it dislocates with the proximal pole of the navicular while the remaining portion of the lunate and the distal portion of the navicular remain in normal relationship to the rest of the carpus (Fig. 7).

It appears that the usual fracture, dislocation, and fracture-dislocation of the carpus have, as a common denominator, a dislocation or a potential dislocation of the capitate from the lunate. The extent and configuration of the fracture will depend upon the anatomical variation of the articular surfaces of the carpal bones, the direction and extent of the traumatizing force, and the position of the hand in relation to the forearm when the force is applied.

This concept suggests the importance of determining the treatment and prognosis of the individual case. When the navicular is fractured and is anatomically reduced when first examined, it is quite likely that the disrupting force has not had time to damage the ligamentous attachments and, therefore, the blood supply to the proximal fragment. With immobilization, union can be predicted in a relatively short time with uniformly good results.

The slightest displacement of the fragments should make one suspicious of a perilunar dislocation, and when this occurs the situation is entirely different. The incidence of aseptic necrosis of the proximal fragment with accurate reduction (Fig. 8) is close to 50 per cent; without reduction the incidence of necrosis approaches 100 per cent (Fig. 9). Prolonged immobilization will produce fairly good results when the reduction of the dislocation is anatomical; when displacement is allowed to persist there is progressive disintegration of the proximal fragment of the navicular, and the capitate migrates from its position to occupy the space between the distal fragment and the lunate.

FIG. 7

Dorsal dislocation of a portion of the lunate and the proximal navicular.

Removal of the proximal fragment is useless and merely hastens the disintegration of the carpus. In the author's experience, open reduction of the dislocation and fixation of the fractured navicular has yielded uniformly poor results. Aseptic necrosis of the navicular fragment has always resulted and the author has observed that the extensive ligamentous stripping necessary to gain a normal capitate-lunate-triangular relationship frequently leads to a fibrous ankylosis.

It is the author's practice to recommend arthrodesis of the wrist at once in all cases of perilunar dislocation with fracture of the navicular when an anatomical reduction cannot be obtained by closed methods. This procedure shortens the period of disability

FIG. 8

Aseptic necrosis of the proximal fragment occurs in 50 per cent of the cases of perilunar transnavicular fracture despite anatomical reduction.

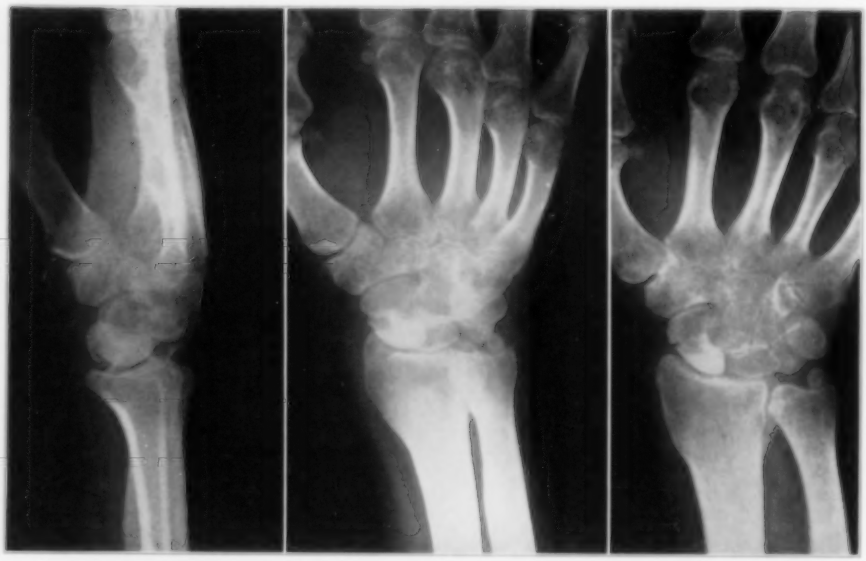

FIG. 9

With incomplete reduction, aseptic necrosis approaches 100 per cent.

and suffering. In performing arthrodesis on an unreduced perilunar dislocation, care must be taken to align the carpus accurately, particularly the capitate-lunate joint. If the lunate is overlooked and left in a flexed position the operation usually releases the

FIG. 10

Removal of the proximal fragment results in rapid disintegration of the carpus as the capitate attempts to reach the radius.

dorsal lunate ligament, resulting in a volar subluxation of the lunate, and a postoperative median-nerve palsy may occur (Figs. 11-A and 11-B).

FIG. 11-A

FIG. 11-B

Figs. 11-A and 11-B: During arthrodesis of an unreduced perilunar dislocation, the lunate will escape into the carpal canal and may result in a postoperative median-nerve palsy unless the perilunar dislocation is reduced at the time of operation.

Failure to obtain an anatomical reduction by closed methods when the navicular is not fractured (Fig. 12) indicates the necessity for open reduction. In this procedure there is no danger of aseptic necrosis of the navicular, and the establishment of a normal intercarpal relationship results in a stable useful wrist. A certain amount of joint motion is lost, however, and traumatic arthritis often develops, particularly adjacent to the fracture of the radial styloid process and between the navicular and the lunate, which causes discomfort of the wrist with extremes of motion and excessive use of the hand. In performing open reduction, a dorsal approach is used and the radial and ulnar borders of the lunate are defined, care being taken to preserve intact the dorsal radial-lunate portion of the capsule. By gentle manipulation, the wrist is "set up" about the lunate. Accurate reduction is verified by the return of the proximal navicular and the triangular

FIG. 12

Failure to obtain an accurate reduction with closed methods indicates the necessity of open reduction when the navicular is intact.

to the radial and ulnar aspects of the lunate. By this method accurate reduction can be obtained with a minimum of ligamentous stripping.

When the lunate is dislocated and there is no associated fracture of the navicular, closed reduction produces good results. When this method of reduction is used, the incidence of aseptic necrosis is very low but it does occur (Fig. 13). With open reduction, the incidence of aseptic necrosis is very high. Removal of the lunate is unsatisfactory for it usually results in a weak wrist. As a rule, when this is done arthrodesis is ultimately necessary because of the disruption of the carpus resulting from migration of the capitate into the space formerly occupied by the lunate. When there is dislocation of the lunate with a fragment of the navicular, the reduction is rarely accurate and aseptic necrosis of the fragment and of the lunate is a common consequence. Primary arthrodesis would be the treatment of choice.

## SUMMARY

1. An attempt has been made to demonstrate the fact that most fractures and dislocations of the carpus follow a sequential pattern. The primary loss of relationship

occurs at the junction of the fixed axis of the hand with the forearm (the capitate-lunate joint) resulting in a perilunar dislocation of the wrist.

2. Manifestations of the basic perilunar dislocation will vary in individual cases depending upon the direction and power of the deforming force, the anatomical differences in the various carpal bones, the ligamentous structures, and the state of the muscles while the injury is occurring.

3. The result of treatment in the individual case can be predicted by recognizing the presence and the extent of associated fractures, particularly of the navicular, and by the accuracy of reduction when closed methods are used.

FIG. 13

In cases of lunate dislocation, aseptic necrosis is uncommon when reduction can be obtained by closed methods, but it does occur as illustrated here. Removal of the lunate rarely produces satisfactory results. Arthrodesis is usually the treatment of choice.

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## DISCUSSION

DR. E. B. KAPLAN, NEW YORK, N. Y.: This excellent presentation has clarified a number of points which have been obscure to me. I believe that it is extremely important to take into consideration the

(*Continued on page 1230*)

# Spontaneous Rupture of Extensor Tendons in the Hand Associated With Rheumatoid Arthritis *

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Spontaneous rupture of tendons of the hand is not a rare occurrence, although it has not recently been described in the literature. In 1896 rupture of the extensor pollicis longus was described by Dūms as drummers' palsy because of its high incidence among members of the German army drum corps. At first mistaken for a paralytic condition, it was soon recognized as a true rupture caused by chronic synovitis associated with attritional change in the body of the extensor tendon. The same syndrome has been recognized as an occupa-

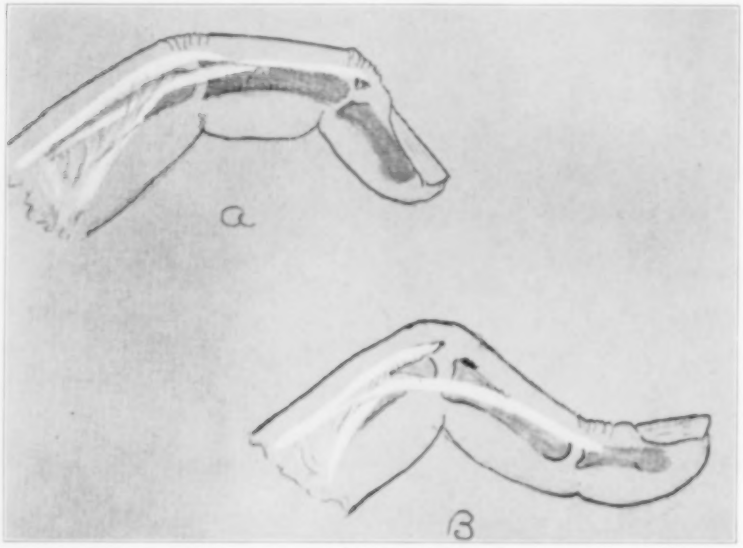


FIG. 1

Fig. 1, *a*: mallet finger; *b*, boutonnière deformity.

tional hazard among tailors, carpenters, and cane makers. The first successful surgical treatment is credited to Duplay; in 1876 he repaired a lesion in a woman, thirty-six years old, by suturing the extensor carpi radialis longus to the distal portion of the extensor pollicis longus.

During the past thirty years, the most frequently reported spontaneous ruptures of tendons in the hand have been those associated with fractures of the distal end of the radius. Infection and degenerative joint changes have also been reported as etiological factors. In addition, spontaneous ruptures have been described as occurring in association with rheumatoid synovitis and as a result of long-standing rheumatoid arthritis of the inferior radio-ulnar joint. It is to this latter group that we shall presently refer in greater detail.

Normal tendons seldom, if ever, rupture except at their ends as the result of strain. This has been repeatedly stated in the literature [15,16] and has been borne out by our own

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experience. Acute trauma to the extensor tendons most often produces mallet finger or boutonnière deformity (Fig. 1). In the flexor tendons, rupture at the point of insertion or at the muscle-tendon junction is the most likely result. Adams reported the case of a seaman who suffered a traumatic amputation of the distal phalanx of the long finger as a result of a door-jam injury. When he withdrew his hand, the flexor digitorum profundus tendon was ruptured at the muscle-tendon junction and the entire tendon emerged from the end of the finger.

Of interest is the type of spontaneous tendon rupture which occurs under normal or light stress when the central portion of the tendon has been weakened by degenerative or traumatic change. The most common example of this is rupture of the extensor pollicis longus tendon following fracture of the distal end of the radius. This complication usually occurs in individuals over the age of thirty-five years and is more common in women than in men. About twenty-six such cases have been reported in the English and American literature[2, 4, 7, 13, 15, 17, 19, 21, 24], and 148 have been thoroughly reviewed by von Stapelmohr in Germany. Oppolzer and Horwitz estimated that spontaneous rupture of this tendon occurs in one of every 270 cases of Colles' fracture. Two cases of similar rupture of the extensor digitorum communis tendon following fracture have been reported by Gladstone.

FIG. 2

The extensor pollicis longus tendon passes medial to Lister's tubercle.

It will be remembered that the extensor pollicis longus tendon passes medial to Lister's tubercle close to the junction of that prominence with the dorsal carpal ligament (Fig. 2). At this point it curves sharply in a lateral direction to become the dorsal boundary of the anatomical snuff-box before entering the thumb. Von Stapelmohr found that most of the ruptures in his series of cases took place either in the carpal tunnel adjoining Lister's tubercle or just proximal to this area.

Borsay and his associates studied the effect of repeated intense strains by applying prolonged stimuli to the muscles of hares and dogs. They were able to produce degenerative changes, microscopic tears, and, eventually, complete rupture of the tendons; and they suggested that they thus duplicated the effects of age. Age appears to be a definite factor in the repeated occurrence of all types of tendon rupture in the hand. The youngest patient whose case has been recorded was a fourteen-year-old girl [14]. Most other patients have been at least in their twenties, and the lesion is most common in patients over thirty-five.

Kleinschmidt experimentally produced fractures of the lower end of the radius in cadavera. In each case he found a small tear in the extensor pollicis longus tendon caused by a small fragment of bone; he felt that this finding indicated that a main factor in the occurrence of delayed tendon rupture is attritional disturbance in the tendon occasioned by irritative tenosynovitis. McMaster found that a tendon can be broken by normal pull if one-half or more of its girth is cut, while Hauck and Weigeldt both postulated that degenerative changes in these tendons are caused by tearing of the mesotendon with interruption of the blood supply and resulting avascular necrosis. Trevor, in supporting the latter theory, cited the finding of Weigeldt that the blood supply to the central tendon

decreases significantly after the age of twenty-five. He presented a case of his own in which necrosis had occurred in the extensor pollicis longus tendon and in one of the extensor digitorum communis tendons in the absence of surface irritation; in the latter tendon, the site of the necrosis was far distant from the fracture. It is probable that a combination of several of these factors is responsible for delayed tendon ruptures following fractures of the wrist.

Other factors that have been held responsible for producing degenerative changes leading to spontaneous rupture of tendons are syphilis, gonorrhoea, tuberculosis, and non-specific local infection. These conditions are seldom seen in this era of antibiotic therapy, however. Local degenerative change from gout or even from Kienböck's disease [11] has been mentioned as an etiological factor in isolated cases.

During the past four years we have observed spontaneous rupture of tendons in the hands of a different group of patients, namely those with long-standing rheumatoid arthritis of the radiocarpal and inferior radio-ulnar joints.

In all of the cases presented here, the rupture was relatively painless and occurred under normal stress.

## CASE REPORTS

Case 1. E. H., a widow, eighty-seven years old, had a twenty-year history of rheumatoid arthritis involving the hands and wrists. In November 1952, at the time of admission, she had pain and weakness in the fourth and fifth fingers of the right hand.

Two months prior to admission, while using a flatiron, she had noted onset of pain and loss of extension. At this time she had also noted a small mass on the back of her wrist.

Examination revealed loss of the last 45 degrees of extension of the fourth and fifth phalanges of the right hand accompanied by gross arthritic deformity of the joints about the wrist and limitation of wrist motion. There was unusual dorsal prominence of the ulnar styloid and also slight thickening of the soft tissues in the region of the tendon sheath just lateral to the ulnar styloid.

Roentgenograms revealed evidence of old arthritic deformity involving the wrist (Fig. 3-A). The radius was relatively shortened as compared to the ulna and the position of the distal end of the ulna was more dorsal than normal.

At operation, November 7, 1952, the tendon of the extensor digiti quinti proprius was found to have been ruptured at the point where it passed the distal end of the ulna. Its ends were frayed and separated. The extensor digitorum communis tendon to the fourth finger was also separated. This lesion appeared to be more recent than the other. There was a lesser involvement of the extensor digitorum communis tendon to the third finger without rupture, and the extensor tendons to the index finger were mildly involved. A prominence had formed under the tendons on the distal end of the ulna, and there was a major articulation of this bone at the wrist. The tendons were pressed dorsally against the extensor retinaculum by the prominent, irregularly placed end of the ulna.

Procedure: The distal one and one-half inches of the ulna was resected. The proximal ends of the extensor digitorum communis muscle bellies to the fourth and fifth fingers were located and sutured to the extensor digitorum communis tendon to the third finger. The distal portion of the extensor slips of the fourth and fifth fingers were also sutured to this tendon. Plaster fixation was maintained for three weeks. The patient was last seen on January 4, 1955 (Figs. 3-B and 3-C), at which time she had no complaint. Extension of the fourth and fifth fingers at the metacarpophalangeal joints lacked 10 degrees of being complete.

Case 2. Mrs. F. C., a professional pianist, sixty-eight years old, was admitted to the Hospital in November 1952, because of inability to extend the right fifth finger. Two months prior to admission she had felt a snap in the dorsum of the wrist while lifting a kettle. At that time she had noticed a loss of ability to extend this finger. There had been a prolonged history of rheumatoid arthritis with involvement of hands and wrists.

Examination revealed the distal end of the right ulna to be abnormally prominent dorsally. There was reduction of pronation and supination to less than 50 per cent of normal. The fifth finger could not be actively extended beyond 90 degrees at the metacarpophalangeal joint, and its extensor tendons could not be palpated during function.

Roentgenographic examination of the bones of the fingers and wrist revealed changes characteristic of rheumatoid arthritis (Fig. 4-A). The presence of old degenerative change was particularly striking at the distal radio-ulnar articulation.

At operation, November 5, 1952, the extensor digiti quinti proprius was found to be avulsed at the level of the distal end of the ulna. Its distal tag had become adherent to the dorsum of the fifth metacarpal, and considerable "furring" was present in the other extensor tendons where they crossed the dorsum of the wrist.

The distal end of the ulna was displaced posteriorly causing friction on the undersurface of the tendons; nevertheless, it was not removed.

Procedure: The extensor digiti quinti proprius was sutured to the extensor digitorum communis tendon of the fourth finger.

When the patient was seen by us in January 1953, there was a hyperextension deformity of the fifth metacarpophalangeal joint and flexion was possible only through 20 degrees. At re-operation on February 19, capsulectomy and resection of the lateral ligaments of the fifth metacarpophalangeal joint were performed. The tendons were freed of scar tissue and the distal end of the ulna was resected. When last seen in December 1955 (Figs. 4-B and 4-C), the patient had no complaints. She was still employed as a pianist, although she could not reach a full octave. The extensor tendons of the fourth and fifth fingers were bowed at the wrist, but the range of motion of these fingers was normal.

CASE 3. Miss M. D. W., aged fifty-four, came to the Clinic in November 1954, with a complaint of inability to extend the right thumb. She worked as a telephone operator and had a fifteen-year history of rheumatoid arthritis with particular involvement of the hands and enlargement of the dorsum of the wrists (Fig. 5-A). Three months prior to visiting the Clinic she had noted a painful snap at the dorsum of the right

FIG. 3-A

Case 1. Preoperative roentgenograms made November 3, 1952.

hand and had since been unable to extend the thumb (Fig. 5-B). There was also dropping of the fifth finger and some weakness of extensor power in the other metacarpophalangeal joints.

At operation on June 16, 1955, hypertrophy of the synovial membrane of the dorsal tendon sheaths beneath the extensor retinaculum was found. The extensor pollicis longus tendon was completely ruptured where it crossed the distal end of the radius. The periosteum had been eroded in this area, exposing the rough underlying surface of the bone. The abductor pollicis longus was similarly ruptured, and the slips of the extensor digiti quinti proprius were frayed and completely ruptured where they passed over the distal end of the ulna, which was prominent dorsally. The extensor slips to the index, long, and ring fingers were intact but were considerably attenuated as a result of the pressure exerted by both the ulna and the hypertrophied synovial membrane.

Procedure: A subtotal synovectomy was done, and the distal end of the ulna was resected. The extensor carpi radialis longus was used to provide power for thumb extension as well as for thumb abduction. Extensor slips to the fifth finger were sutured into the intact extensor tendon of the ring finger.

On August 4, 1955, the patient returned to work. She was last seen in January 1956 (Figs. 5-C and 5-D). At that time she had active extension of the four fingers, and she could also extend the distal phalanx of the thumb, but only when the metacarpophalangeal joint was flexed.

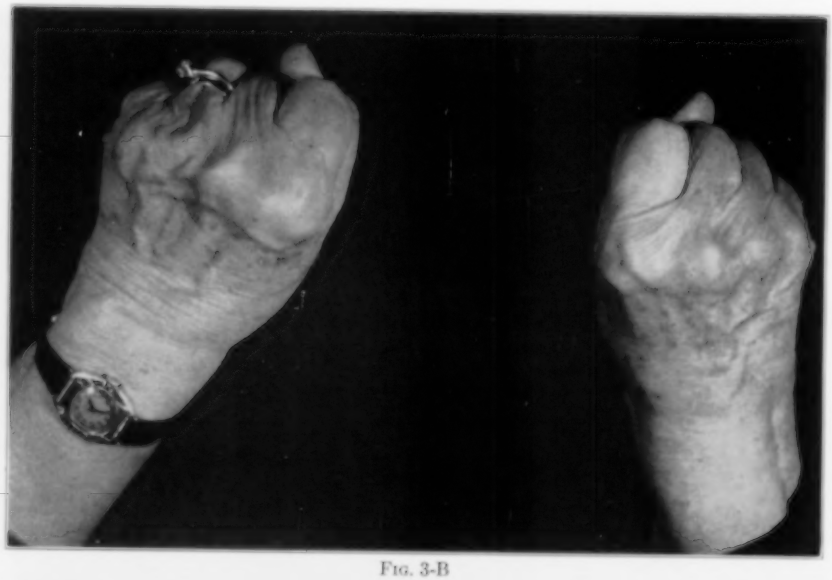

FIG. 3-B

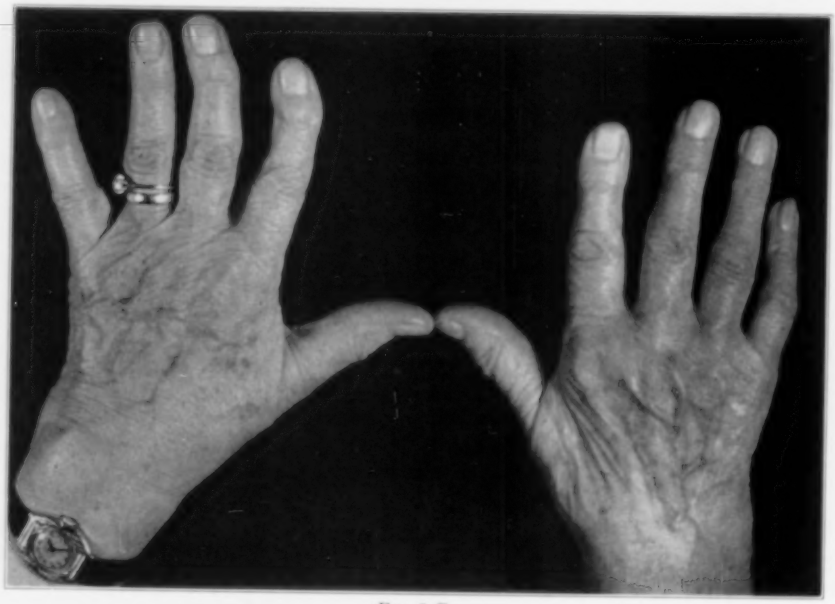

FIG. 3-C

Figs. 3-B and 3-C: Photographs taken January 4, 1955.

CASE 4. Mrs. V. M., fifty-one years of age, had suffered low-grade rheumatoid arthritis for five years prior to coming to the Clinic in February 1955. She complained of inability to extend the fifth finger of the right hand. She had struck this finger against a packing box five weeks prior to her visit. She did not complain of pain. She could extend the metacarpophalangeal joint to 150 degrees but no further. The function of her other fingers was normal, but there was some thickening of the wrist with prominence of the ulna dorsally at the inferior radio-ulnar joint.

Roentgenograms showed advanced degenerative changes at the wrist with dorsal subluxation of the distal end of the ulna. She has not as yet accepted operative correction.

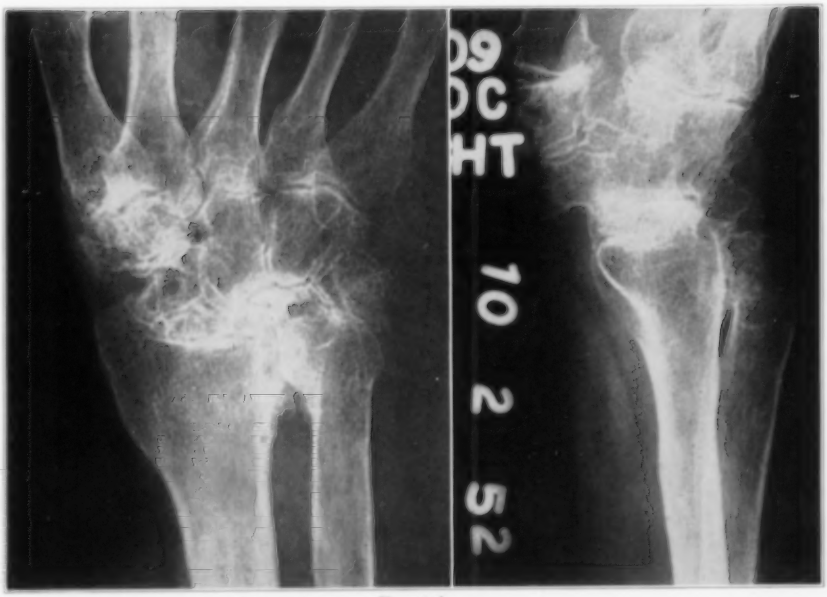


FIG. 4-A

Case 2. Preoperative roentgenograms.

FIG. 4-B

FIG. 4-C

Figs. 4-B and 4-C: Photographs taken December 1955.

CASE 5. Miss H. O'H., a housewife, fifty-three years of age, was seen in January 1955, complaining of loss of power in the fourth and fifth fingers of the right hand. In August 1954, she had had a series of hydrocortisone injections into the right wrist. After the fifth injection, she had noticed a gradual progressive weakness of extension in the fourth and fifth fingers. This had become total in three days.

Clinical examination revealed dorsal prominence of the distal end of the ulna and typical findings of rheumatoid arthritis in the hands. There was no function of the extensor digitorum communis tendons to the third, fourth, and fifth fingers.

Roentgenographic examination revealed evidence of severe, old rheumatoid arthritis with posterior displacement of the ulna at the wrist joint.

This patient has thus far refused surgical repair.

Of frequent occurrence in the rheumatoid hand is the development of mallet finger or boutonnière deformity. In these hands local synovial changes in the lesser finger joints produce conditions favorable for tear by weakening the extensor slips. A typical example of this type of lesion is Case 6.

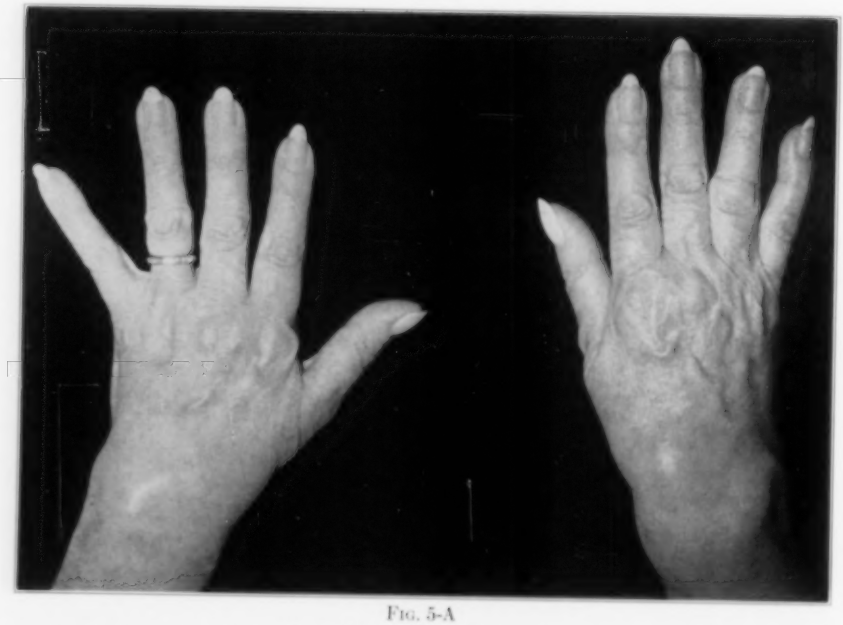

FIG. 5-A

Case 3. Preoperative photograph.

FIG. 5-B

Preoperative roentgenograms of the right hand, made June 14, 1955.

CASE 6. Mrs. F. L., a fifty-eight-year-old housewife, came to the Clinic in December 1954, with a three-month history of weakness in the fourth finger of the left hand. This weakness had developed following a strain caused by pulling down a zipper on parlor furniture. She also had a ten-year history of chronic swelling about both wrists and hands. She had typical changes of rheumatoid arthritis with dorsal prominence of the ulnar styloids, and she had a mallet-finger deformity of the fourth finger with inability to extend the distal phalanx.

Spontaneous rupture of the flexor tendons has also been reported as occurring in hands with rheumatoid arthritis.

CASE 7. Mrs. M. M. came to the Clinic in July 1954 because of a swelling of the right wrist and right ankle. After a period of study, a diagnosis of rheumatoid arthritis was established. Because of the persistence

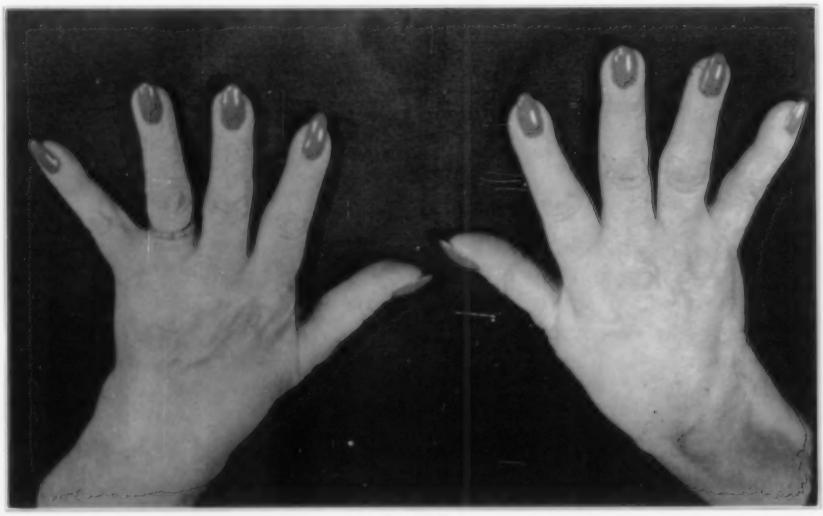

FIG. 5-C

FIG. 5-D

Figs. 5-C and 5-D: Photographs taken January 1956.

of the volar prominence of the wrist, the appearance of a compound palmar ganglion, and the weakness of flexion in the index finger, an operation was performed on June 16, 1955. The findings at that time included marked synovial hypertrophy and villosynovitis of the portions of the flexor tendon sheaths which lay beneath the carpal ligament. Complete attenuation of the flexor digitorum sublimis and profundus tendons to the index finger was also found at this point, and the proximal portions of these tendons were found to be retracted about three inches above the flexor crease of the wrist. There was no exposure of bone, but there was marked narrowing of the carpal tunnel as a result of hypertrophy of the soft tissues. A free tendon graft was used to repair the index-finger tendon of the flexor digitorum profundus. The flexor digitorum sublimis was resected and a synovectomy was done. When last seen, the patient had about 60 per cent of normal function in the index finger.

The lesions in the first five cases reported here (Fig. 6) represent a unique group of spontaneous tendon ruptures. It is felt that these lesions resulted from (1) attritional change in the tendon as a result of rheumatoid synovitis; (2) attrition due to age; and (3) increased mechanical wear and tear due to the prominence of the distal end of the ulna. The extensor retinaculum allows little space for expansion, and in Case 7 the transverse carpal ligament provided the same mechanical pressure that the ulnar prominence on the dorsum of the wrist provided in Cases 1 through 5.

FIG. 6

Fig. 6: Rupture of the extensor tendons over the subluxated distal end of the ulna.

Tendon rupture is not spontaneous in the true sense of the word, for the break occurs at a point of mechanical stress. It is to be noted that although the basic attritional changes which are caused by rheumatoid arthritis may remain after the source of mechanical pressure has been removed, the tendons may, nevertheless, be repaired so that they will provide good function.

We have found only one reference to this condition in the literature: a report of two cases by Vaughn-Jackson. The patients in both these cases were males, fifty-seven and sixty-six years old respectively. Both had ruptures of the extensor digitorum communis tendons of the fourth and fifth fingers in the region of the distal end of the ulna. Neither was reported to have rheumatoid arthritis, but in both cases it was found at operation that there was roughening of the distal end of the ulna. This roughening had produced a lesion in the floor of the tendon sheath, thereby affecting the tendons. The distal ends of the ulnae were resected and the tendon defects were repaired successfully by means of free tendon grafts.

It is our belief that spontaneous tendon rupture is not rare in the arthritic hand but is probably overlooked because of the severity of other deformities in these patients.

## CONCLUSION

Spontaneous rupture of the extensor tendons of the hand has been found in five patients with long-standing rheumatoid arthritis and subluxation of the distal end of the ulna at the inferior radio-ulnar joint. Findings at operation in three of these patients

indicated that the rupture was caused by degenerative changes in the floor of the extensor-tendon groove in the region of the distal end of the ulna. Satisfactory results were obtained by tendon repair combined with resection of the distal end of the ulna.

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## DISCUSSION

Dr. S. Benjamin Fowler, Nashville, Tennessee: Dr. Straub and Dr. Wilson have presented an excellent and interesting paper which certainly should enlarge our knowledge of reparable defects in rheumatic hands. The problem of pathological conditions of the tendons in these hands is very real, but, unfortunately, little attention is paid to it by the men who treat rheumatoid arthritis. These men generally consider finger deformities to be a direct result of pathological conditions of the joints and, while this is sometimes true, it more often is not, especially when the interphalangeal joints are involved. Finger deformities may result from such mechanical derangements as subluxation of the extensor tendons at the metacarpophalangeal

(*Continued on page 1334*)

# Studies of the Hip Joint by Means of Lateral Acetabular Roentgenograms

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In the following investigation studies were made of 400 normal and abnormal hip joints by means of a lateral roentgenographic view of the acetabulum.

It is recognized that there are several variable anatomical factors present in congenital dislocation of the hip. The anterior projection of the acetabulum, or the relationship of the acetabulum to the long axis of the patient's body, appears to be an important factor in determining the head-to-acetabulum relationship. Accordingly, the authors have attempted to work out a method of measuring the angle made by the acetabulum with the sagittal plane of the body. While developing this method, they devised a technique

FIG. 1

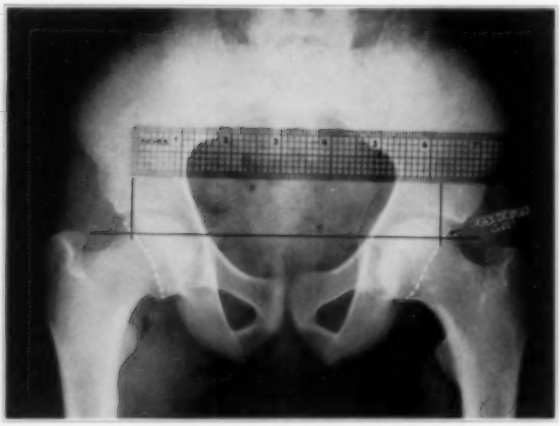

FIG. 2

Fig. 1: Patient seated in position for lateral roentgenogram of the acetabulum to be made. The position of the pelvis is stabilized by the seat. The x-ray tube is tilted so that it forms an angle of 30 degrees with the long axis of the pelvis. The metal markers on the seat appear on the roentgenograms as lines. These lines may be used in aligning the two roentgenograms in order to reconstruct a complete view of the pelvis.

Fig. 2: Anteroposterior roentgenogram. The posterior lips are identified, and the method of measuring the distance between the lips is indicated.

for making roentgenograms of the hip joint. As a result of this technique, other studies of the acetabulum are now possible; these will be described later.

In an extensive search of the literature to determine what measurements of the acetabulum had previously been made, the only records of similar measurements that could be found were those reported by LeDamany[2,3]. He attempted to trace the evolution of the acetabular cavity from quadruped to biped. He felt that the anterior obliquity of the hip socket is a vestige of a more primitive species and spoke of this construction and of anteversion of the femur as faults which may be present in extreme forms.

## METHOD

Series of roentgenograms were made. These included a lateral acetabular roentgenogram of each hip joint, an anteroposterior roentgenogram of the pelvis and hips, and an

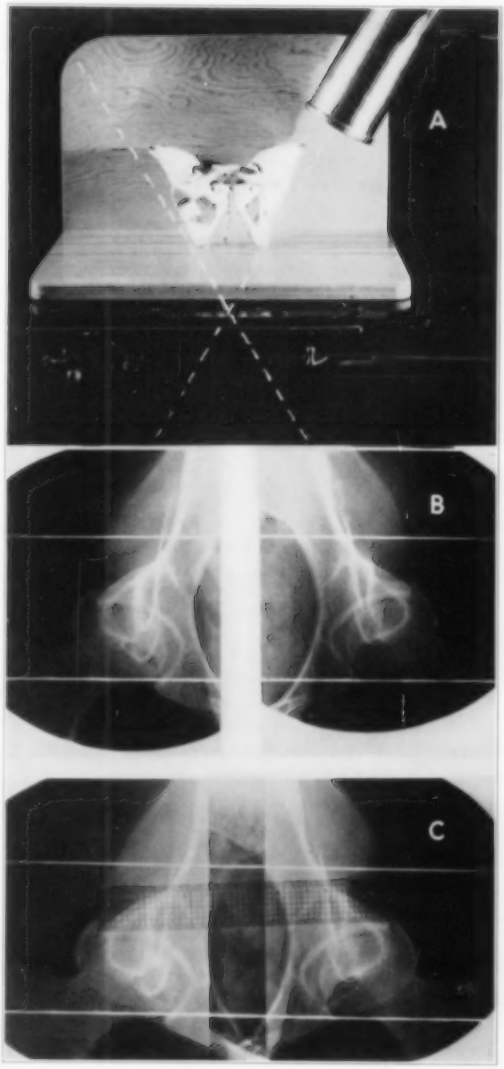


Fig. 3, *A*. Position of the pelvis as the roentgenogram was made.

Fig. 3, *B*. A lateral view of each acetabulum has been obtained.

Fig. 3, *C*. In order to combine the two roentgenograms into a single complete view of the pelvis, the lines representing the metal markers are aligned and the posterior lips are separated by a distance which is equal to that found by measurements made on the anteroposterior roentgenogram. A line is then drawn from the posterior lip of one acetabulum to the posterior lip of the other (shown by the ruler). In this case the line is not parallel to the marker lines, for the patient was slightly twisted on the seat and the marker lines had to be corrected to allow for this twist.

anteversion roentgenogram of each femoral neck, the latter made by a method described by one of the authors and associates in an article published in 1953 [1].

One technique used by the authors to obtain the lateral roentgenogram of the acetabulum was to seat the patient on a wooden bracket which had metal marker strips on the seat portion (Fig. 1). These metal strips appeared on the roentgenograms as image lines which were later used to orient the roentgenograms for measurements of the angles of the pelvis. The device of using metal markers is helpful but not necessary.

The patient is placed in the seated position with the thighs together and flexed to 90 degrees. The x-ray tube is placed parallel to the coronal plane of the body, and the Bucky diaphragm is placed so that the film is at right angles to and centered beneath the patient's mid-line. The tube is tilted until it forms an angle of 30 degrees with the long axis of the body, and an extension cylinder is centered over the iliac crest. The 30-degree angle was found to result in the least superimposition of parts. A substitute view of patients in traction has been obtained by flexing the unaffected limb at right angles and placing the cassette against the perineum. This was done rather than angle the film between the lower extremities, which is the routine method of obtaining lateral hip roentgenograms.

In this series, roentgenograms were made of each acetabulum. The patient was positioned as described, and the first roentgenogram was made. Then the tube was transferred to the opposite side, without the patient being moved, and a second roentgenogram was made by the identical technique.

The resulting roentgenograms were used to reconstruct a superior-inferior image of the pelvis. The width of the pelvis was determined by measurements made on the antero-

posterior roentgenogram, the posterior lips of the acetabula being used as reference points (Fig. 2). The two lateral roentgenograms were aligned in the transverse plane by superimposing the images of the metal bars on each other (Figs. 3, *A* and 3, *B*). The distance between the posterior acetabular lips, as measured on the anteroposterior view of the pelvis, was used to establish the distance between the posterior acetabular lips in the combined lateral acetabular view. This facilitated orientation of the separate acetabular roentgenograms to form a complete view of the pelvis. A straight line was then drawn across the two roentgenograms from the posterior lip of one acetabulum to the posterior lip of the other (Fig. 3, *C*). This line served as a base line. A perpendicular was erected to this base line at its point of intersection with the posterior lip of one of the acetabula. A third line was then drawn through this point and projected through a corresponding point on the anterior lip of the acetabula. The angle this line made with the perpendicular was accepted as the anterior obliquity of the acetabulum (Fig. 4).

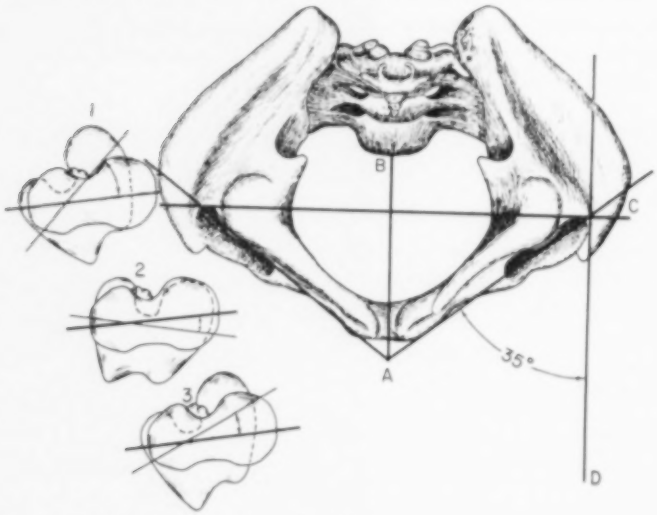


FIG. 4

This inferior-superior view of the pelvis shows the acetabula without the overlying ilia. The line between the two posterior lips is the base line. At the point of intersection of this line with one of the posterior lips, a perpendicular, *CD*, has been erected, and between this same point and the anterior lip, another line, *CA*, has been drawn. The resulting angle *ACD* has been found to range from 32 to 35 degrees. This drawing inaccurately suggests that this angle is greater than 35 degrees.

## EXPERIMENTAL STUDIES

In order to check the feasibility and accuracy of this method of obtaining lateral acetabular roentgenograms, a series of roentgenograms was made of skeletons and mechanical devices (Fig. 5). The roentgenograms of the skeletons were made with the pelvis tilted forward on the ischia and the femora flexed at right angles; the procedure was also carried out with the pelvis tilted backward. This method, in effect, rotated the acetabula with the result that measurements could be made from different approaches. There was no source of error with the pelvis at zero degrees, nor was there any if the roentgenogram of the acetabulum was made with the anterior superior spine, the middle portion of the acetabulum, and the tuberosity of the ischium in a straight line, perpendicular to the x-ray table. When the skeleton was tilted 15 degrees forward or backward, the maximum source of error was reached; this was −10 degrees for extension and +10 degrees for flexion.

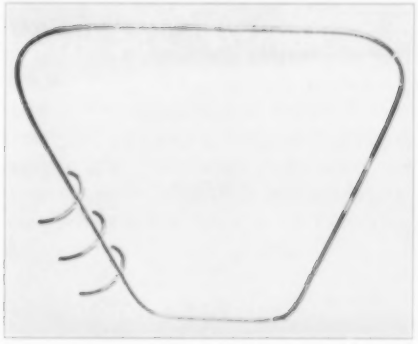

FIG. 5

Fig. 5: The mechanical device used to determine the source of error. A large loop has been bent into the shape of a pelvis. To the side of this loop, three metal half spheres have been welded, the distance between these half spheres being the same as the distance between the first half sphere and the narrow side of the loop, which represents the ischial tuberosities. This device was tilted at various angles in relation to the x-ray beam, and roentgenograms were made. For all the metallic semicircles, the greatest error was about 10 degrees.

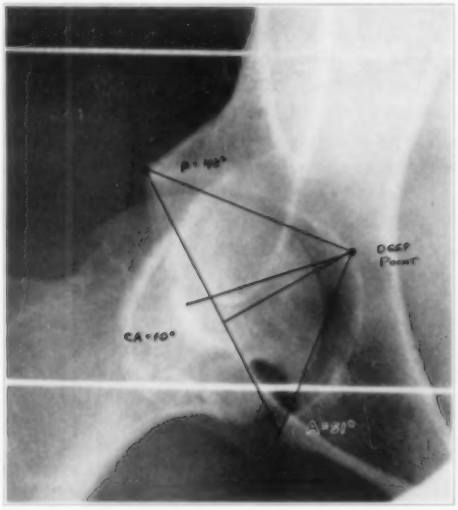


FIG. 6

Fig. 6: In this case, the posterior angle of the acetabulum, *P*, is 40 degrees; the anterior angle, *A*, is 51 degrees; and the CA angle is 10 degrees. In order to determine the CA angle, a perpendicular is dropped from the deep point of the acetabulum to the line *PA* and another line is drawn from the deep point to the center of the head of the femur. The center of the head is determined by a method similar to that described by Wiberg.

The acetabula are not true spheres; because of this fact the authors constructed a mechanical pelvis consisting of a wire loop, on the side of which they placed a wire semicircle to correspond to the acetabulum. Two additional semicircles were attached to the same side of this pelvis at intervals that were equal to the interval between the first metal semicircle and the ischial tuberosity. This was done to determine the effect of the distance between the acetabulum and the ischial tuberosity on the incidence of error. Lateral roentgenograms were then made of this mechanical device with the three acetabula on one side. In this device, the distance of the acetabulum from the ischial tuberosity seemed to have no effect on the acetabular measurements. When the mechanical pelvis was tilted forward, it was found that the greatest range of error was 10 degrees, at 15 degrees of flexion. The same was true of extension, and the range of error returned to zero when the central portion of the acetabulum and the ischial tuberosity were parallel to the x-ray beam. The authors concluded, therefore, that the amount of error in the lateral roentgenogram of the acetabulum is negligible because the error can be determined very easily if the roentgenogram has been made with the pelvis in a zero position or if it has been made with the anterior superior spine, the middle portion of the acetabulum, and the ischial tuberosity in a straight line. If the roentgenogram is made by the technique shown in Figure 1, these anatomical structures will be in line. The conclusion that there is a small degree of error is further verified by the fact that our measurements are very close to those of LeDamany, who found, in his laboratory studies with dried specimens, that the forward inclination of the acetabulum was 35 degrees.

In order to obtain a clear lateral roentgenogram of the acetabulum with the least superimposition of other parts, it was necessary to place the cone so that it made an angle of 30 degrees with the patient's sagittal plane and to tilt it in a superior-inferior direction in relation to the acetabulum. The 30-degree angle is similar to the angle that the wing of the ilium makes with the sagittal plane in the anteroposterior view.

## NORMAL FINDINGS

In this study an attempt was made to observe the normal acetabulum and hip as they appear on lateral roentgenograms. Sets of roentgenograms, including an anteroposterior view of the pelvis, anteversion views of each femur, and lateral views of each hip were made of 100 adults and of 100 children ranging in age from infancy to ten years. Measurements were then made on each set. It was found that there was practically no variation in the angle of forward obliquity of the acetabulum in children of different ages.

Measurements of anteversion were made in order to see if there is any correlation

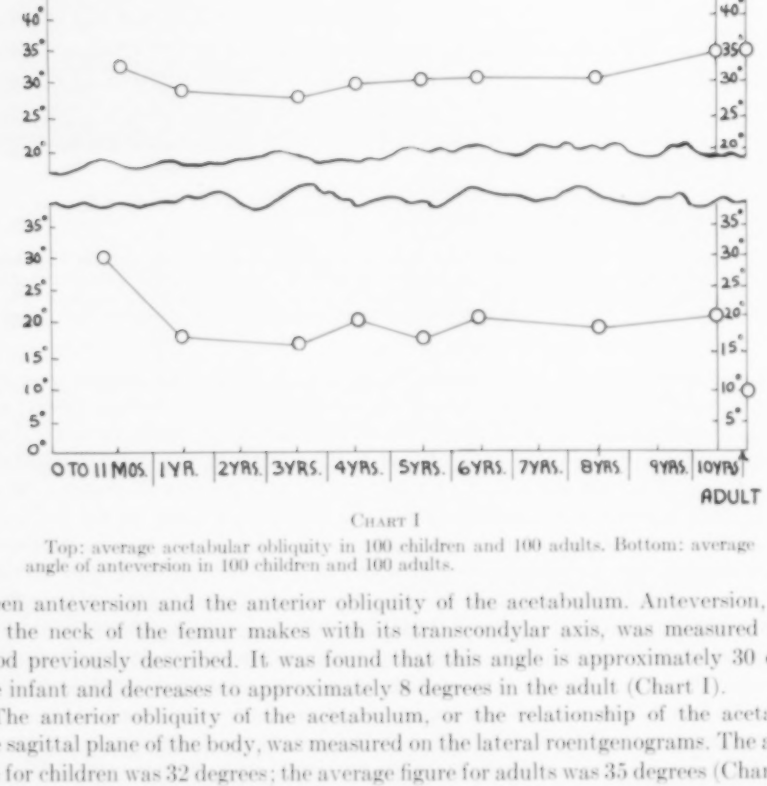


CHART I

Top: average acetabular obliquity in 100 children and 100 adults. Bottom: average angle of anteversion in 100 children and 100 adults.

between anteversion and the anterior obliquity of the acetabulum. Anteversion, or the angle the neck of the femur makes with its transcondylar axis, was measured by the method previously described. It was found that this angle is approximately 30 degrees in the infant and decreases to approximately 8 degrees in the adult (Chart I).

The anterior obliquity of the acetabulum, or the relationship of the acetabulum to the sagittal plane of the body, was measured on the lateral roentgenograms. The average figure for children was 32 degrees; the average figure for adults was 35 degrees (Chart I).

Other angles of the acetabulum were measured, including an anterior and a posterior angle. These angles were determined in the following manner. A line was drawn on the lateral roentgenogram from the anterior lip of the acetabulum to the posterior lip. Two other lines were then drawn, one from the anterior acetabular lip to the deepest point of the acetabulum and the other from the posterior acetabular lip to the deepest point of the acetabulum. The acetabulum, as observed in the lateral roentgenogram, is not a portion of the circumference of one sphere but is rather a portion of the circumference of two spheres with its deepest portion occurring at the point where the circumferential lines of the spheres intersect. This point may be used as the point representing the deepest part of the acetabulum (Fig. 6). In infants, the area of the triradiate cartilage was used as the point representing the deepest part of the acetabulum. The anterior angle, or the angle

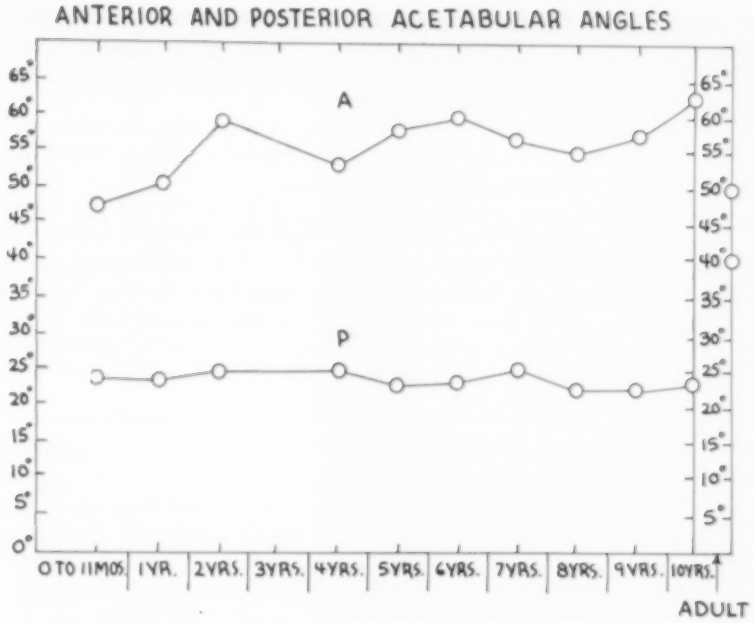


CHART II

A: the average anterior angle of the acetabulum in 100 children and 100 adults. P: the average posterior angle of the acetabulum in 100 children and 100 adults. This graph was made by using the triradiate cartilage as the deepest point.

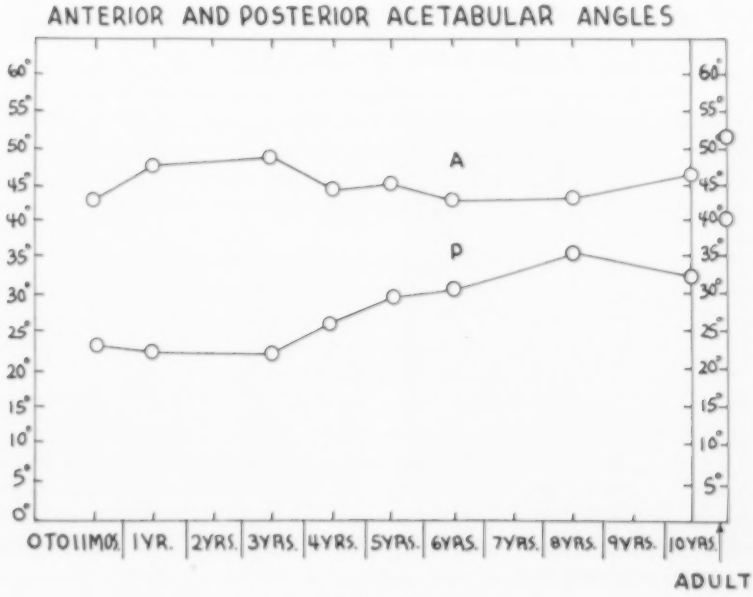


CHART III

A: the average anterior angle of the acetabulum, the deepest point of the acetabulum rather than the triradiate cartilage being used to determine the angle. P: the average posterior angle of the acetabulum in children and adults, the deepest point being used to determine the angle.

which had its apex at the anterior lip, was found to average 51 degrees in the adult group. The posterior angle was found to be 40 degrees. From a study of these figures a mental image of the anatomy of the acetabulum, as it appears when viewed laterally, may be constructed.

The findings of a study of the younger subjects revealed that the adult acetabulum is not an enlarged version of a child's acetabulum, indicating that a definite change in growth pattern occurs as bone development progresses.

Two sets of figures were obtained for the young group. In one set, the triradiate cartilage was used as the deep reference point (Chart II). In the other, the observed deepest point of the acetabulum was used (Chart III). In the infant group, the observed deepest point was also the area of the triradiate cartilage, but in children over the age of one year, it was observed that the deepest point had shifted posteriorly. By using the triradiate cartilage as the point of reference, the contributions to the growth of the ace-

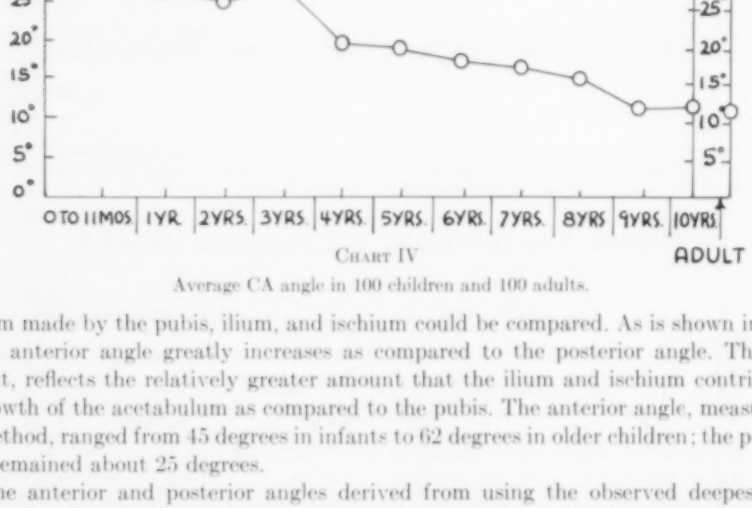


CHART IV

Average CA angle in 100 children and 100 adults.

tabulum made by the pubis, ilium, and ischium could be compared. As is shown in Chart II, the anterior angle greatly increases as compared to the posterior angle. This, it is thought, reflects the relatively greater amount that the ilium and ischium contribute to the growth of the acetabulum as compared to the pubis. The anterior angle, measured by this method, ranged from 45 degrees in infants to 62 degrees in older children; the posterior angle remained about 25 degrees.

The anterior and posterior angles derived from using the observed deepest point of the acetabulum as the point of reference suggest that the acetabulum is flatter in young children than it is in adults and that with maturity it deepens and the point of greatest depth moves posteriorly. The anterior angle remains about 45 degrees while the posterior angle ranges from 25 degrees in infants to 35 degrees in older children.

The CA angle is a measurement of the relationship of the head of the femur to the acetabulum in the anteroposterior direction when the hip is flexed at 90 degrees (Fig. 6). It is similar to the CE angle of Wiberg, which is a measurement of the head-acetabulum relationship in the lateral direction. The reference points used in obtaining the CA measurement on the lateral roentgenogram are the deep point of the acetabulum, the center of the head of the femur, and the point at which a line drawn from the deep point of the acetabulum would form a right angle with the line connecting the anterior and posterior lips. Lines connecting these three points form an angle which demonstrates the head-acetabulum relationship. The normal CA angle was found to be greatest in the young. It is approximately 25 degrees in the infant and decreases to about 10 degrees in the adult (Chart IV). The figures obtained in normal hips in our study were remarkably constant.

Fig. 7-A: Case 1. Anteroposterior roentgenogram showing fractures of the femoral shaft and acetabulum with posterior dislocation. It is difficult to determine the dislocation in this view.

FIG. 7-A

In derangements of the hip joint, changes in the CA angle, as measured on the lateral roentgenograms, reflect the loss of joint relationship, as do changes in the CE angle, as measured on the anteroposterior roentgenogram. As the head of the femur subluxates, there is progressive increase in the CA angle beyond the normal.

## DISCUSSION

In the past the hip has been studied in many ways, but the use of a pair of roentgenograms of the acetabula made with the thighs flexed at right angles is not listed as a standard procedure in any text so far as the authors have been able to discern. There are times in the practice of orthopaedics when lateral roentgenograms of the hip joint showing critical detail would be of definite value in diagnosis and subsequent treatment. It can be assumed that, just as the lateral view is important in diagnosing pathological conditions of the long bones, it is also important in the study of pathological conditions of the acetabulum. Several pathological

FIG. 7-B

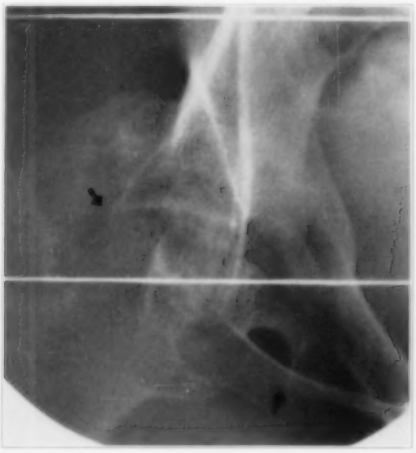

FIG. 7-C

Fig. 7-B: Lateral roentgenogram of the hip. The acetabulum is empty, the head of the femur being located behind the posterior lip.

Fig. 7-C: A large mass of bone developed on the posterior lip of the acetabulum following healing of the fracture. Note the deformity of the acetabulum as reflected by the abnormally large distance between the anterior lip and the femoral head. Compare Fig. 8-D.

FIG. 8-A

FIG. 8-B

Fig. 8-A: Case 2. Anteroposterior roentgenogram showing a fracture dislocation.

Fig. 8-B: Lateral roentgenogram. Note the size of the fragment, the subluxation of the joint, and the extent of the base of the fracture site. A study of these findings is of aid in determining the type of treatment.

FIG. 8-C

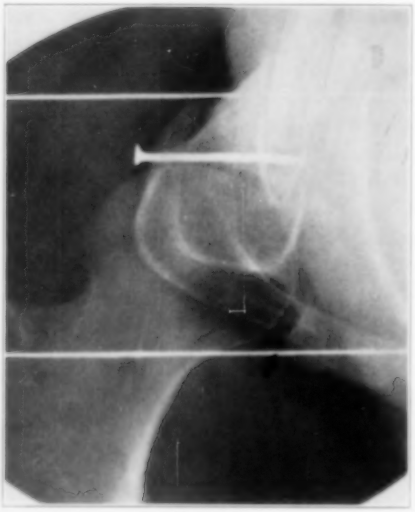

FIG. 8-D

Fig. 8-C: Anteroposterior roentgenogram made following open reduction and internal fixation of fracture fragment by means of nailing.

Fig. 8-D: Lateral roentgenogram. The dislocation has been reduced, and the fracture fragment has been fixed by means of a nail.

conditions of the hip are presented in the following case studies. The roentgenograms shown in connection with these cases contribute to a better understanding of the normal and pathological anatomy of the hip.

In the past stereographic and oblique roentgenograms have given helpful information. They have not, however, provided more than vague information concerning the relationship of the structures about the acetabulum—except for the lateral aspect of the pelvis which has been shown with the opposite side superimposed. The view which we use is duplicated in part by conventional lateral roentgenograms of the hip, but in these views the thickness of the soft parts has prevented satisfactory visualization of the acetabulum. By flexing the thigh at right angles to the pelvis, the thickness of the soft tissues is markedly reduced even in heavy patients. In over 400 examinations, the lateral roentgenograms have been of a sufficient quality to be useful in diagnosis. (This technique is offered as an

FIG. 9-A

FIG. 9-B

Fig. 9-A: Case 3. Anteroposterior roentgenogram showing old congenital dislocation of the hip.

Fig. 9-B: Lateral roentgenogram. Only a small portion of the head of the femur is in contact with the posterior lip of the acetabulum.

aid in revealing the relationship of the head of the femur to the acetabulum.) Although the roentgenogram of the head-acetabulum relationship is made with the thigh in 90 degrees of flexion, it has been shown in our clinical cases that the information obtained is accurate and useful.

No conclusions could be drawn in this study as to the relationship of the anterior obliquity of the acetabulum to congenital dislocation of the hip as only normal pelves were studied. It is felt that use of this new technique, supplemented by our description of normal findings, should promote further understanding of some of the basic pathological entities of the hip joint.

## CASE REPORTS

CASE 1. A twenty-year-old colored soldier was severely injured in an automobile crash. He suffered multiple fractures involving the left lower extremity. These included a comminuted segmental fracture of the upper part of the femur, a fracture-dislocation of the hip joint, and fractures of the acetabulum. It was difficult to determine the direction of the dislocation of the head of the femur by means of the routine anteroposterior and stereographic views of the pelvis (Fig. 7-A). The lateral acetabular roentgenogram, made with the patient in bed in traction, revealed that the dislocation was posterior and that the acetabulum was fractured into two main fragments through the area of the Y cartilage (Fig. 7-B). The authors were then able to decide on a course of treatment. Open reduction of the fracture was done, and the femoral fragments were fixed by means of an intramedullary nail. The dislocation was also reduced by open reduction. All the fractures united, and the head of the femur remained viable. A large amount of ossification occurred around the acetabulum, especially about the posterior portion. The residual deformity of the healed acetabulum was well demonstrated in the lateral acetabular roentgenogram (Fig. 7-C).

Dislocations of the hip joint associated with fractures of the femur are rare, difficult to diagnose, and difficult to treat. The lateral acetabular roentgenogram was a definite aid in diagnosing this dislocation and provided information which facilitated treatment.

CASE 2. A thirty-year-old soldier was involved in an automobile accident and suffered a posterior dislocation of the hip joint with fracture of the posterior acetabular lip (Fig. 8-A). Lateral acetabular roentgenograms revealed the posterior dislocation and demonstrated a large fracture fragment of the posterior lip (Fig. 8-B). The dislocation was reduced by closed methods and the fragment of the posterior lip was replaced at open reduction. Postoperative roentgenograms showed the reduction to be good (Figs. 8-C and 8-D).

FIG. 10-A

FIG. 10-B

Fig. 10-A: Case 4. Anteroposterior roentgenogram of the pelvis showing short, club-like femora with lateral dislocation of the hip.

Fig. 10-B: Lateral acetabular roentgenogram of the right hip. (The arrows indicate the anterior and posterior lips of the acetabulum.)

FIG. 10-C

FIG. 11-A

Fig. 10-C: Lateral roentgenogram showing the posterolateral dislocation. (The arrows indicate the anterior and posterior lips of the acetabulum.)

Fig. 11-A: Case 5. Anteroposterior view of the pelvis showing changes in the head and neck of the femur and in the acetabulum of the right hip.

In posterior dislocation with fracture of the posterior lip of the acetabulum, operative intervention is often necessary in order to replace the fractured fragment and to assure stability of the hip socket. In this case the lateral acetabular roentgenogram revealed the fractured fragment in good detail without superimposition of other structures. This view can be an aid in the treatment of such injuries by enabling the surgeon to determine more accurately the size of the fragment, its degree of comminution, and the position of the head of the femur with relation to the acetabulum.

CASE 3. The patient in this case was a twenty-eight-year-old physician who gave a history of congenital dislocation of the right hip. He walked with a marked Trendelenburg gait and complained of fatigue on walking or standing. The anteroposterior roentgenogram revealed a deformed femoral head which was subluxated laterally (Fig. 9-A). The lateral acetabular roentgenogram revealed that the amount of actual contact between the femoral head and the posterior portion of the acetabulum was small (Fig. 9-B).

FIG. 11-B

FIG. 11-C

Fig. 11-B: Lateral roentgenogram of the left hip, which is essentially normal. (The arrows point to the anterior and posterior lips of the acetabulum.)

Fig. 11-C: Lateral acetabular roentgenogram of the right hip, showing the changes in the head and neck of the femur and in the acetabulum, especially the posterior portion. (The arrows point to the anterior and posterior lips.)

The routine anteroposterior roentgenogram does not give a full picture of the pathological anatomy of the hip joint. In this case the routine view suggested fair approximation of joint surfaces, while the lateral acetabular roentgenogram showed that there was actually little contact within the joint and that there was a rather marked posterior displacement of the head. The lateral acetabular roentgenogram of the hip joint may help in the further understanding of congenital dislocation of the hip joint, its treatment, and its prognosis, for by means of this view the anterior dislocation can be differentiated from the posterior dislocation, the placement of the acetabular roofs can be evaluated, and posterior subluxation, not revealed in the routine view, can be evaluated as to its importance. Following study of the lateral roentgenogram, treatment may be instituted as deemed necessary.

CASE 4. This patient was a ten-month-old, white male with congenital shortness of the femora, harelip, and cleft palate. The anteroposterior roentgenogram of the pelvis demonstrated short, club-like femora with lateral dislocation of the hips (Fig. 10-A). In a lateral acetabular roentgenogram of the right hip, it could be seen that the dislocation was both lateral and posterior (Fig. 10-B). The lateral acetabular roentgenogram of the left hip joint revealed that the dislocation in this hip was also both lateral and posterior (Fig. 10-C).

CASE 5. This patient was an eight-year-old girl who had been exposed to tuberculosis when she was four years old. Pulmonary tuberculosis, with associated tuberculosis of the right hip, had developed. She was treated in a sanatorium with bed rest and streptomycin and was followed in the orthopaedic clinic. She wore an ischial weight-bearing brace for two years. When last seen, the patient walked without a limp and had a 25-degree flexion contracture in the hip with a loss of 10 degrees of internal and external rotation. An anteroposterior roentgenogram of the pelvis demonstrated abnormal changes in the neck and head of the right femur and in the acetabulum of the right hip (Fig. 11-A). A lateral acetabular roentgenogram of the left hip showed this joint to be essentially normal (Fig. 11-B). The lateral acetabular roentgenogram of the right hip also showed pathological changes in the neck and head of the femur and in the acetabulum, especially the posterior portion (Fig. 11-C).

It was felt that the child had a synovial type of tuberculosis with secondary involvement of the bone structures. In cases of pathological conditions of the hip, a lateral acetabular roentgenogram can be of use in the differential diagnosis and in determining the progress of the disease.

NOTE: All drawings in this article were made by Private Herman Bloss. Mrs. Jane Kornegay, Mr. Arthur Riley assisted in making the roentgenograms, and Dr. A. R. Shands, Jr. assisted in the preparation of the paper. Cases 4 and 5 were seen in the Orthopaedic Clinic of the Blodgett Hospital, Grand Rapids, Michigan.

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## DISCUSSION

### PERILUNAR DISLOCATIONS

*(Continued from page 1207)*

blood supply to the bones of the carpus. There are two ligaments of great importance in maintaining the blood supply to the navicular and the lunate, and in an open reduction it is important to avoid this area as much as possible. Destruction of these two ligaments is probably often responsible for aseptic necrosis.

DR. HANS MAY, PHILADELPHIA, PENNSYLVANIA: What type of arthrodesis was used?

DR. JOSEPH H. BOYES, LOS ANGELES, CALIFORNIA: I would like to ask Dr. Wagner if, in removal of the lunate bone, he has tried to fix the navicular to the capitate in any way?

DR. WAGNER (closing): I agree with Dr. Kaplan that most of us are inclined to forget that the ligaments of the carpal joints conduct the blood supply to the bones of the hand. When it is necessary to strip off the ligamentous attachments in order to reduce a dislocation, the resultant loss of blood supply is serious. This is why I stress closed reduction as a treatment of choice.

Dr. May asked what type of arthrodesis is used. We approach the wrist dorsally and perform an exeresis — that is, we excise the articular cartilage and the stratum durum of the navicular, the radius capitate, the lesser multangular, the lunate, and the triangular. Then, raising the proximal (from the radius) and the distal (from the capitate and third metacarpal) osteoperiosteal flap, a bed is prepared for a corticocancellous graft from the ilium. This is held firmly in place when the wrist is dorsiflexed.

I have had no experience in fixing the navicular to the capitate in order to prevent the migration of the capitate when the proximal pole of the navicular disintegrates or is removed. I think, however, that the same difficulty would be experienced as occurs in intercarpal fusion. I believe that removal of the entire navicular and lunate would give more satisfaction when motion of the wrist must be maintained.

# Calculation of the Angle of Anteversion by Means of Horizontal Lateral Roentgenography *

BY DONALD J. MAGILLIGAN, M.D., BROOKLYN, NEW YORK

For a period of somewhat more than five years, routine roentgenographic examination of the hip at St. Charles' Hospital has been done in two planes. One of these is the anteroposterior roentgenogram and the other is a horizontal lateral roentgenogram [3]. Primarily, the purpose of examination in two planes is to determine as accurately as possible the position of the femoral head in relation to the acetabulum. The method of making these roentgenograms has been described in detail in a paper by Laage and his associates. Upon further study of this technique it was noted in the horizontal lateral roentgenogram that there was visualized an angle between the femoral shaft and neck which appeared to correspond to the angle of anteversion. Study of this angle is a topic of currently mounting interest. Decision was made, therefore, to investigate further the possibility of determining the angle of anteversion from the roentgenograms made according to our routine technique. By paying particular attention to certain details of the technique, the angle of anteversion can be calculated from the value of the angles projected onto the film in both the anteroposterior and the horizontal lateral roentgenograms. The merit thereof lies in the fact that the patient will be spared additional radiation exposure, time will be conserved, and the need for additional equipment will be obviated.

The beginning of any discussion requires a definition of terms. Inspection of the femur reveals that the neck projects away from the shaft in a direction which can be defined by two angles. It deviates laterally from the shaft, and this angle of lateral deviation has been designated the cervicofemoral angle. It also projects anteriorly, and this angle of anterior projection is commonly known as the angle of anteversion. Some consideration must be given to the fact that the femoral shaft bows slightly laterally and slightly anteriorly. Account must be taken also of the fact that the anterior projection of the neck may be due to torsion of the shaft or to true version at the junction of the neck and shaft, or to both. A basis for deriving the true angle of anteversion must be constructed in the light of these considerations and this can be done in the following manner.

As a starting point one must assume that there is a line through the center of both femoral condyles at a right angle to the long axis of the femur and in the coronal plane of the femur (Figs. 1, *A* and 2). This is called the diacondylar line. There is next postulated a point in the proximal portion of the femur at the junction of the shaft and neck. Such a point must be theoretically in the center of this portion of the femur (Point *P*, Fig. 1, *B*). It is assumed that a plane lies on this point and on the diacondylar line. This shall be called the diacondylar plane and shall be used as a base plane in this discussion (Fig. 1, *B*). A second plane is then assumed to extend through the long axis of the neck of the femur lengthwise along the femoral shaft. This is called the cervical plane (Fig. 1, *C*). The angle at which the cervical plane intersects the diacondylar plane is the true angle of anteversion (Fig. 1, *D*). The model constructed from an adult femur (Fig. 2) shows graphically what is meant by the angle of anteversion. It is interesting to note that, in this particular specimen, the angle measures 23 degrees. The model illustrates the fact that there is only one way in which the true angle of anteversion can be dissociated from the cervicofemoral angle and projected onto a film as a single angle. This requires that the x-ray beam be directed through the long axis of the femur and that the cassette be

* Based on an exhibit presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 1953.

held perpendicular to it (Fig. 2). Such an approach was attempted by Dunn, but it was found that the shadows of the condyles and of the soft tissues overlay the shadow of the femoral neck so as to obscure it almost completely. Roentgenographic portrayal of the femur from any other position must necessarily produce a projected cervicofemoral angle and a projected angle of anteversion, neither of which represents the true value of these angles. It is recognized that at times the value of the projected angle may coincide with

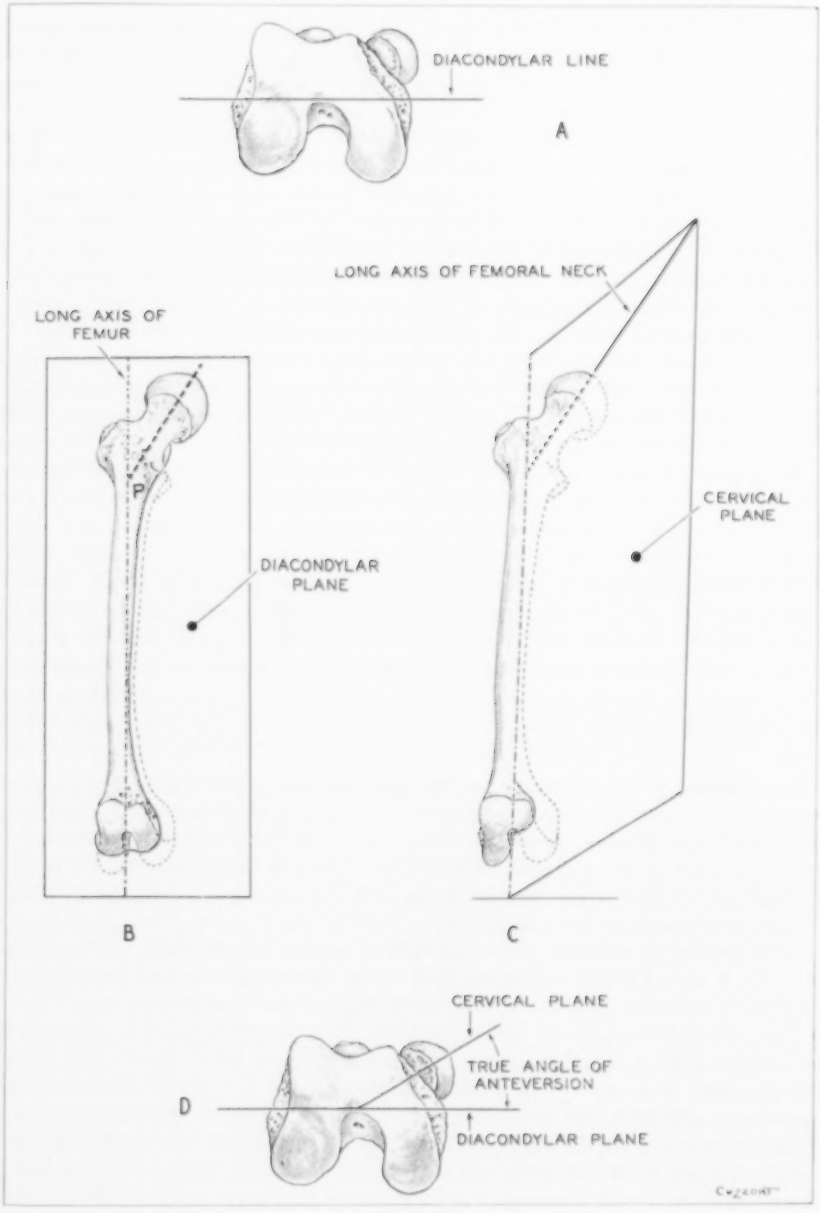



FIG. 1

A graphic portrayal of the definition of the angle of anteversion.

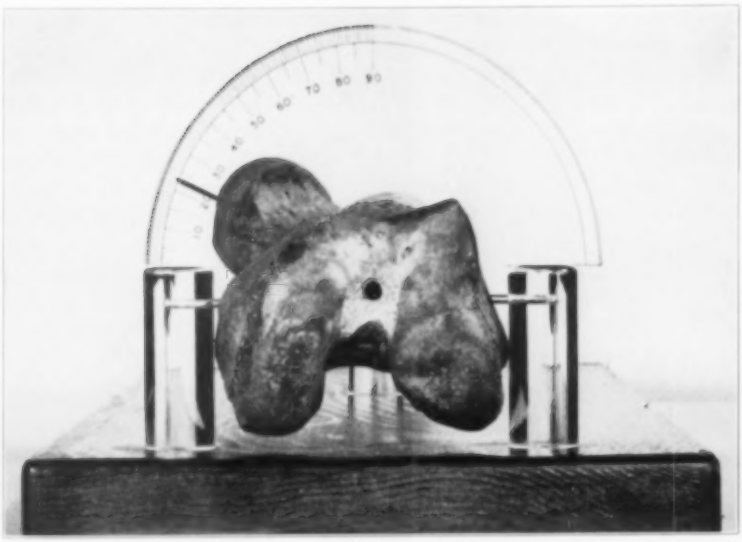


FIG. 2

A model prepared from an adult femur shows by means of metal rods and a lucite scale the true angle of anteversion.

that of the true angle. This, however, is a matter of chance, and it will be shown that the question of determining the true angle of anteversion with any degree of certainty resolves itself into a mathematical problem.

Recognition of this principle led to further studies by other investigators. Dunlap and Shands and their associates published a study in which they demonstrated the ap-

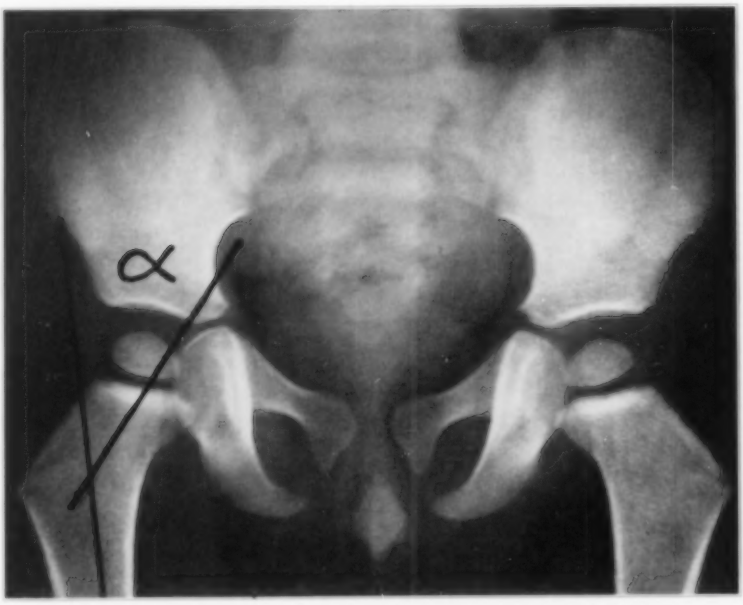



FIG. 3

Anteroposterior roentgenogram shows the projected cervicofemoral angle (α).

plication of this principle by means of a special positioning apparatus. With this apparatus, the extremity is precisely positioned and a frog lateral roentgenogram is made. On this film the apparent angle of torsion is measured. A postero-anterior roentgenogram is used to show the apparent angle of inclination. The true angle of torsion is calculated from these apparent angles by means of a trigonometric formula. Another study based on this principle was presented by Ryder and Crane. A special positioning apparatus is used, and an abduction roentgenogram which shows an apparent angle of anteversion is made. In this the position of the tube and the direction of the beam is not varied in relation to the pelvis, but is the same as that used in making the anteroposterior view. The projected angle of anteversion shown on the abduction roentgenogram and the projected angle of inclination shown on the anteroposterior view are measured; from these values the true angle of anteversion is calculated by means of a trigonometric formula.

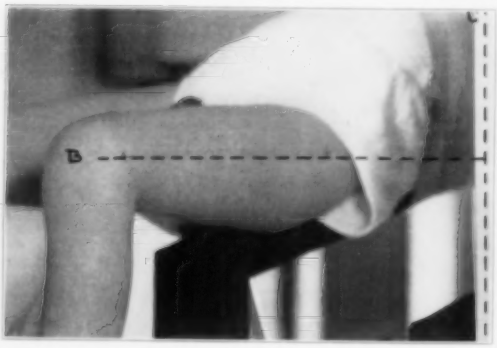



FIG. 4

FIG. 5

Fig. 4: Position of the cassette (*C*) in relation to the diacondylar plane (line *B*). The thigh, and therefore the diacondylar plane, is parallel to the table. The cassette, in a special holder, is at a right angle to the table and is therefore at a right angle to the diacondylar plane.

Fig. 5: This photograph illustrates the position of the cassette in relation to the table and to the diacondylar plane.

The method being presented here embodies the same principle. As stated earlier in this paper, roentgenographic examination in two planes is used routinely in order to determine the relationship of the femoral head to the acetabulum. If particular attention is paid to certain details, the anteroposterior and horizontal lateral roentgenograms made according to our technique can be used for the solution of this problem. It cannot be solved from either view alone. The manner of making these roentgenograms has been described in detail by Laage and his associates. It is to be noted that the position of the patient and his extremities remains constant. In making the anteroposterior view the head of the x-ray tube is centered as accurately as possible over the hip joint. Every effort must be made to hold the femur parallel to the table and in neutral rotation. Since the diacondylar plane will then be parallel to the table, it will also be parallel to a cassette placed on the table, under the hip joint. An anteroposterior roentgenogram made in this position will reveal a projected cervicofemoral angle, designated angle $\alpha$ (Fig. 3). This is an almost universally routine manner of making an anteroposterior roentgenogram and requires no special demonstration. For the horizontal lateral roentgenogram, the cassette is held against the lateral side of the thigh and trunk, and the head of the x-ray tube is placed between the thighs. If it is to be of value in calculating the angle of anteversion, this view must be made with the face of the cassette held at a right angle to the diacondylar plane (that is, at a right angle to the table) as shown in Figures 4 and 5. It must also be held parallel to the long axis of the femoral neck (Figs. 6 and 7). The long axis

FIG. 6

FIG. 7

Fig. 6: Parallel position of the cassette in relation to the long axis of the femoral neck.
Fig. 7: This photograph illustrates the same parallel relationship in the model.

of the femoral neck is first determined from the anteroposterior roentgenogram. The position of the trunk is not changed. The head of the tube is brought down between the thighs to the level required for the horizontal lateral roentgenogram. The cassette is placed in the holder which is so constructed that a cassette held in its slots will be perpendicular to the tube. The holder is then placed in position on the table so that the edge of the cassette rests against the patient's flank, as shown in Figures 6 and 7. It may at times be necessary to vary slightly the degree of abduction of the femur. This does not affect the calculation since the mathematical formula is based entirely on lines and planes contained in the femur. On a roentgenogram made according to this technique

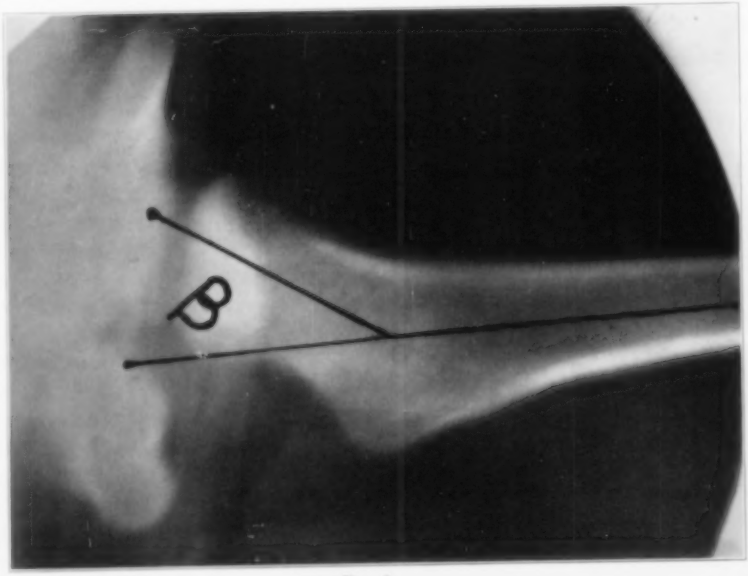



FIG. 8

Horizontal lateral roentgenogram shows the projected angle of anteversion ($\beta$).

there will be shown a projected angle of anteversion, designated angle $\beta$ (Fig. 8). Knowing the values of these two angles, it is possible to calculate from them the value of the true angle of anteversion, designated angle $\beta'$.

It should be noted here that, since the angle of anteversion involves only the femur, the position of the femur in relation to the pelvis is of no consequence. Hence, our routine positioning with the hip at a 20-degree angle of flexion does not affect the validity of the calculation, if the femur is held parallel to the table. The degree of abduction or adduction can be varied so as to fulfill the specification that the cassette be placed parallel to the femoral neck. This is the essential requirement and the position of the extremity relative to the mid-line of the trunk is immaterial. This is the fundamental difference between our method and those proposed by other writers.

It has been stated that determination of the true angle of anteversion from the two projected angles resolves itself into a mathematical problem. The solution of this problem

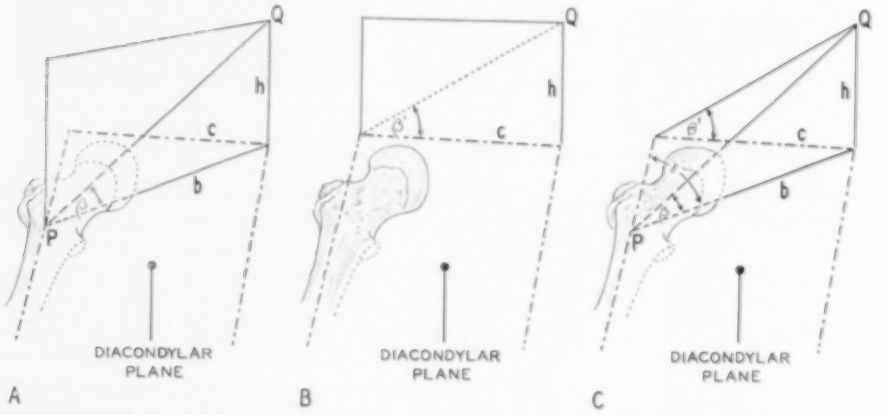



FIG. 9

A schematic drawing which illustrates the construction of the geometric figure described in the text. *A*, a plane constructed through the long axis of the femoral neck perpendicular to the diacondylar plane; *B*, a plane erected beyond the femoral head perpendicular to the diacondylar and cervical planes; and *C*, the pyramid formed by the intersection of the designated planes.

is found in the construction of a geometric figure. Two of the sides of this figure are formed by the diacondylar and cervical planes, the derivation of which has previously been explained. These two planes are extended out into space beyond the proximal end of the femur. A third plane is then constructed through the long axis of the femoral neck, perpendicular to the diacondylar plane (Fig. 9, *A*). This plane contains angle $\beta$. The final element is a plane erected perpendicular to the long axis of the femoral shaft (Fig. 9, *B*). It will thus be perpendicular also to the diacondylar plane and the cervical plane. This plane contains the angle $\beta'$. The figure thus constructed is a pyramid, the four sides of which are right-angle triangles (Fig. 9, *C*). The height of this pyramid and the length of the sides of the triangles need not be known. It will be seen from the diagram that one angle of the side which lies in the diacondylar plane is angle $\alpha$, the value of which can be found on the anteroposterior roentgenogram. One angle of an adjoining side (lying in the third plane) is the angle $\beta$, which is determined from the horizontal lateral roentgenogram. The last plane to be erected contains the angle $\beta'$, the true angle of anteversion.

Calculation of the value of $\beta'$ from the known values $\alpha$ and $\beta$ can be done by using the trigonometric functions of these angles. In order to simplify understanding of the calculation, a diagram has been prepared representing the three essential triangles opened out into a single plane (Fig. 10). Since the fourth side, which lies in the cervical

plane, is not used in the calculation, it has been omitted from the diagram. Referring to the diagram, it is seen that line $b$ is common to triangles one and two. Line $h$ is common to triangles two and three. Line $c$ is common to triangles one and three. Since the length of none of these lines is known, it is necessary to use functions of $\alpha$, $\beta$, and $\beta'$ which contain these common elements. The sine of $\alpha$, the tangent of $\beta$, and the tangent of $\beta'$ fulfill these requirements, and knowing these factors the following equation can be written:

$$\text{Tan } \beta' = \frac{h}{c} = \frac{\frac{h}{b}}{\frac{c}{b}} = \frac{\text{Tan } \beta}{\text{Sin } \alpha}$$

A table of trigonometric functions will rarely be found as part of a physician's armamentarium. In deference to this fact, a graph has been prepared (Fig. 11). Taking all values of angle $\alpha$, from 0 to 90 degrees, and all values of $\beta$, from 0 to 90 degrees, the possible values of $\beta'$ calculated from any combination of $\alpha$ and $\beta$ within these ranges have been determined and are shown in the graph. Since the exactness of the graph exceeds the requirements of ordinary clinical practice, a working table (Fig. 12) has been prepared, based on the graph. In this table the values of $\alpha$ and $\beta$ are given at intervals of 5 to 10 degrees.

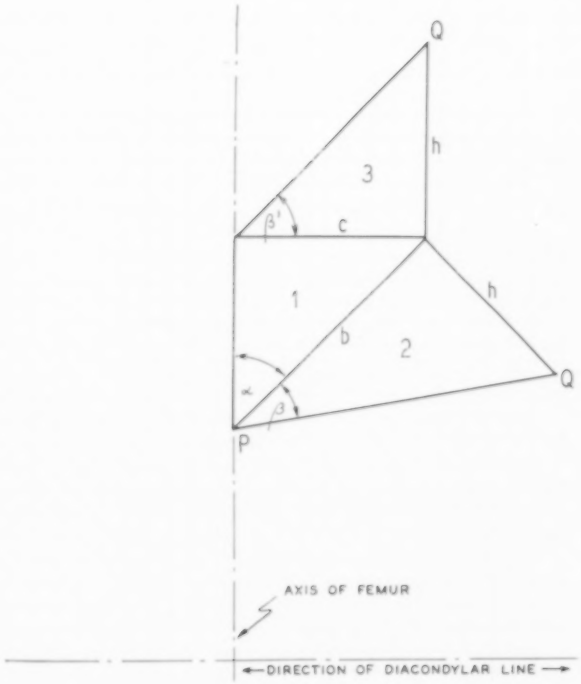



FIG. 10

The sides of the pyramid opened out into a single plane. The fourth side is not presented since it does not enter into the calculation.

Practical application of the method requires only that the angles $\alpha$ and $\beta$ be measured on the anteroposterior and horizontal lateral roentgenograms. The figures thus obtained are located on the table, and the columns which they head are followed to their intersection. At this point will be found the value of $\beta'$, the true angle of anteversion.

In order to demonstrate the method and its application better, a model was prepared from an adult femur (Figs. 2 and 13). Metal rods have been accurately placed in this femur to represent the diacondylar line, the long axis of the neck, and the long axis of the shaft. A lucite scale was mounted perpendicular to the long axis of the shaft, and the bone was cut through at the junction of the long axes of the neck and shaft. This having been done, the angle of anteversion can be varied to any desired degree and measured on the lucite scale. Roentgenograms were made of the model in the anteroposterior and horizontal lateral positions. This was done with the neck at its normal 23-degree angle, and at two arbitrarily chosen angles of 40 degrees and 60 degrees. The projected angles shown on these films were accurately measured. From the values obtained, the

true angles of anteversion were determined, the graph shown in Figure 11 being used. The results are shown in Table I.

In each of the positions, the calculated angle of anteversion coincided with the angle shown on the lucite scale. This is admittedly a small number of determinations. It is presented thus only because of limitations of space and time. There is no reason, however, to believe that a similar result would not be obtained at any other chosen angle. It is felt that this demonstrates the accuracy of the method and of the calculation in a positive manner.

Inspection of the table reveals some interesting facts. The true angle of anteversion is never smaller than the projected angle. It is either equal to it, or, more commonly, greater. As the degree of varus increases, the discrepancy between $\beta$ and $\beta'$ is less. Within the middle ranges, the discrepancy will be mathematically fairly marked but clinically of no great significance. As the cervicofemoral angle approaches a severe valgus deformity, the discrepancy becomes more marked. This is particularly true when the value

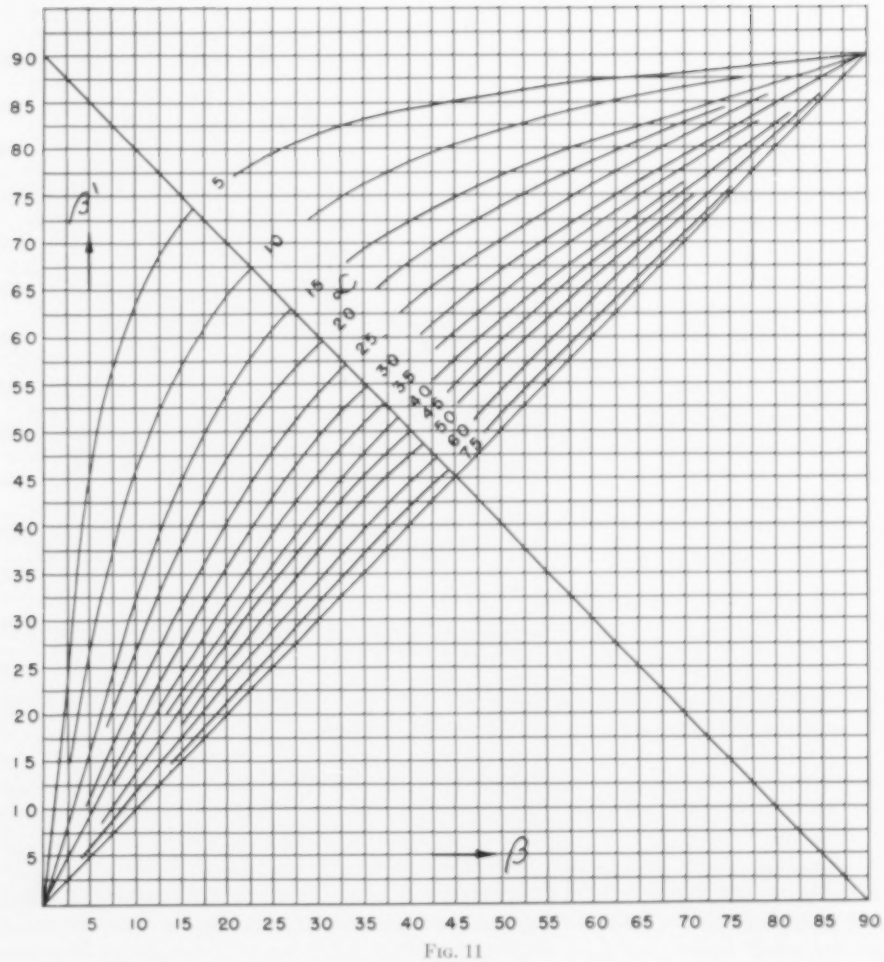



FIG. 11

The mathematical portion of this problem has been worked out completely. With any combination of values of $\alpha$ and of $\beta$, from 0 to 90 degrees, the true angle of anteversion can be found by the use of this graph.

TABLE FOR THE DETERMINATION OF THE ANGLE OF ANTEVERSION ($\beta'$) FROM THE PROJECTED ANGLE OF ANTEVERSION ($\beta$) HORIZONTAL LATERAL VIEW AND FROM THE PROJECTED CERVICO FEMORAL ANGLE($\alpha$) ANTERO POSTERIOR VIEW.

| Enter $\beta$ ↓ / Enter $\alpha$ → | 100 (80) | 110 (70) | 120 (60) | 130 (50) | 135 (45) | 140 (40) | 150 (30) | 160 (20) | 170 (10) |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 10 | 11 | 12 | 13 | 14 | 15 | 19 | 27 | 46 |
| 20 | 20 | 21 | 23 | 25 | 27 | 29 | 36 | 47 | 64 |
| 25 | 25 | 26 | 27 | 31 | 33 | 36 | 43 | 53 | 69 |
| 30 | 30 | 31 | 34 | 37 | 39 | 42 | 49 | 60 | 73 |
| 35 | 35 | 36 | 39 | 42 | 45 | 48 | 55 | 64 | 76 |
| 40 | 41 | 42 | 44 | 48 | 50 | 52 | 59 | 68 | 78 |
| 45 | 46 | 47 | 49 | 52 | 55 | 57 | 64 | 71 | 80 |
| 50 | 51 | 52 | 54 | 57 | 59 | 62 | 67 | 74 | 82 |
| 55 | 55 | 56 | 59 | 62 | 63 | 66 | 70 | 76 | 83 |
| 60 | 60 | 61 | 64 | 66 | 68 | 69 | 73 | 78 | 84 |
| 70 | 70 | 71 | 73 | 74 | 76 | 77 | 79 | 82 | 86 |
| 80 | 80 | 81 | 82 | 83 | 83 | 83 | 84 | 86 | 88 |

FIG. 12

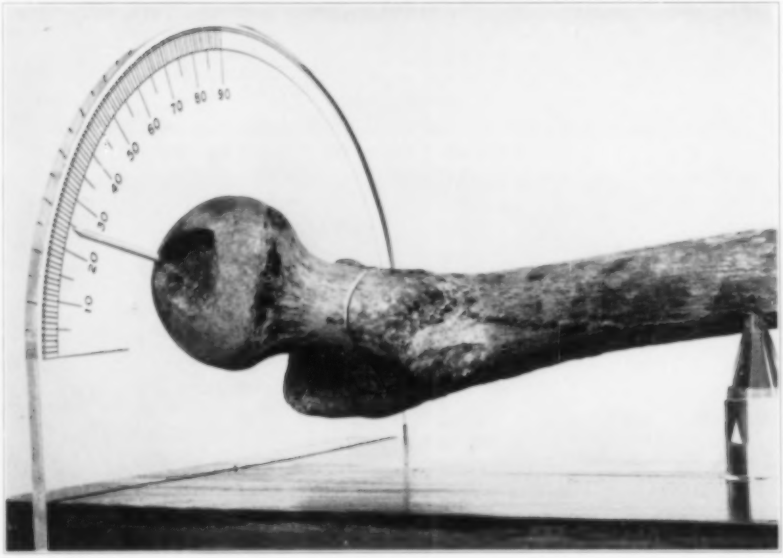



FIG. 13

Another view of the model showing more clearly the lucite scale and the rod representing the long axis of the femoral neck.

of the projected angle of anteversion is in the lower ranges. It can be appreciated, therefore, that when a valgus deformity such as is frequently found in congenitally dislocated hips is accompanied by a small projected angle of anteversion, there is in reality a considerable degree of anteversion present. It is in such cases that this method of calculation has its greatest value.

There is no conceivable way in which this method could be checked clinically. The reason for its origin lies in the fact that direct physical measurement of the angles formed by the femoral neck and shaft in living subjects is impossible. Clinical application of the method, however, is being pursued regularly as part of our routine hip studies. To illustrate the value of the determination, serial roentgenograms of one patient are presented. This patient had unilateral dysplasia, and the angles of anteversion were measured on both the affected and the normal sides. They are shown in Figures 17-A through 20-C. In the roentgenograms and in Table II the angles on the affected side (the right hip) are designated as $\alpha$R, $\beta$R, and $\beta'$R. The angles on the unaffected side (the left hip) are designated as $\alpha$L, $\beta$L, and $\beta'$L. It will be seen that on the dysplastic side there is a considerable variation in the angle of anteversion. It has lessened considerably, most of the diminution taking place in the last year. The unaffected side, however, has changed to only a slight degree, and in a gradual fashion. This serves to illustrate the constancy of the method.

All roentgenograms made in accord with the basic essential requirements of this method are being measured. To date, there has not been accumulated a sufficient number of cases on which to base any valid conclusions. However, over a period of years it is expected that it will be possible to establish average normals for all age groups from

TABLE I

| | | |
|---|---|---|
| 1. With the model set at 23 degrees (Fig. 14). | | |
| Projected cervicofemoral angle | ($\alpha$) | 52 degrees |
| Projected angle of anteversion | ($\beta$) | 18 degrees |
| True angle of anteversion | ($\beta'$) | 23 degrees |
| 2. With the model set at 40 degrees (Fig. 15). | | |
| Projected cervicofemoral angle | ($\alpha$) | 45 degrees |
| Projected angle of anteversion | ($\beta$) | 31 degrees |
| True angle of anteversion | ($\beta'$) | 40 degrees |
| 3. With the model set at 60 degrees (Fig. 16). | | |
| Projected cervicofemoral angle | ($\alpha$) | 35 degrees |
| Projected angle of anteversion | ($\beta$) | 45 degrees |
| True angle of anteversion | ($\beta'$) | 60 degrees |

TABLE II

CALCULATION OF THE ANGLES OF ANTEVERSION ON SERIAL ROENTGENOGRAPHIC STUDIES OF PATIENT C.C. ILLUSTRATING THE VARIATIONS OF THE DYSPLASTIC SIDE AND THE RELATIVE CONSTANCY OF THE UNAFFECTED SIDE.

| | Angle $\alpha$ (*Degrees*) | Angle $\beta$ (*Degrees*) | Angle $\beta'$ (*Degrees*) |
|---|---|---|---|
| Figures 17-A to 17-C | R 25 | R 40 | R 68 |
| 3–24–54 | L 30 | L 45 | L 60 |
| Figures 18-A to 18-C | R 15 | R 33 | R 67.5 |
| 10–5–54 | L 33 | L 43 | L 58 |
| Figures 19-A to 19-C | R 20 | R 30 | R 60 |
| 1–7–55 | L 32 | L 42 | L 58 |
| Figures 20-A to 20-C | R 32 | R 26 | R 45 |
| 1–20–56 | L 35 | L 40 | L 57.5 |

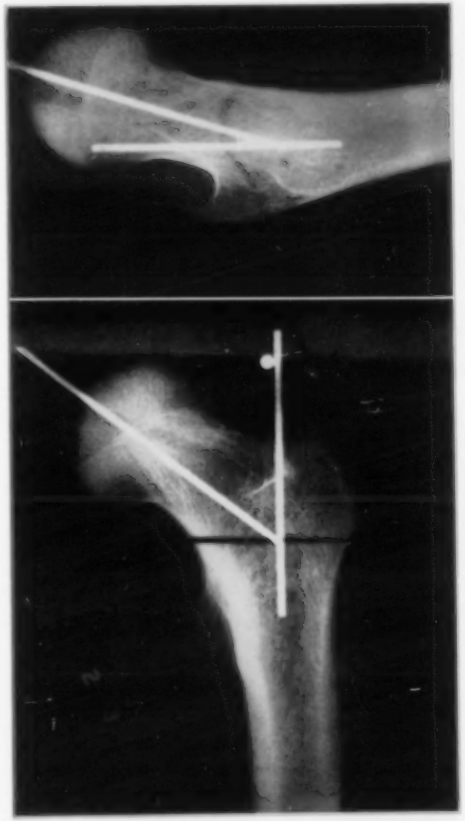


FIG. 14

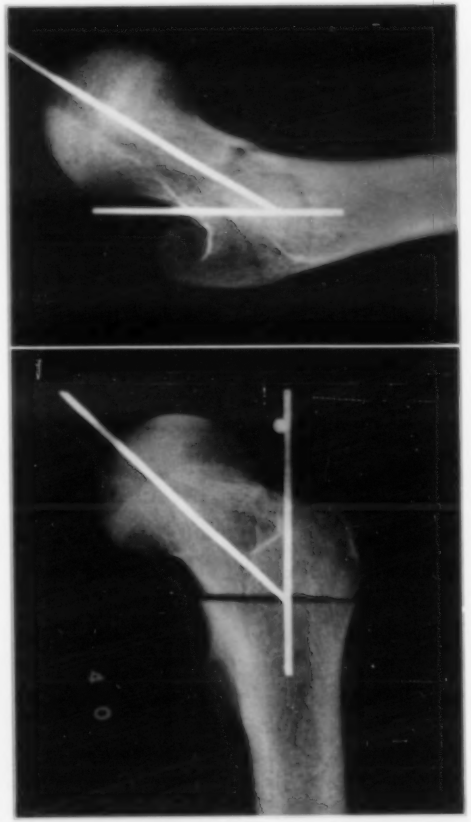


FIG. 15

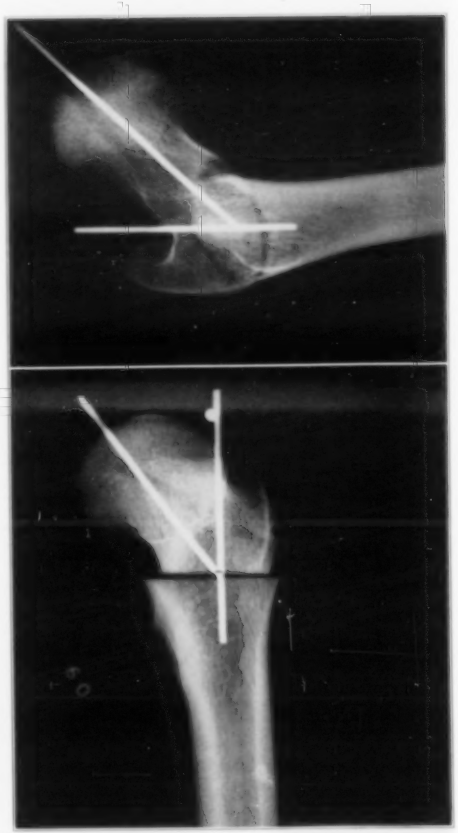
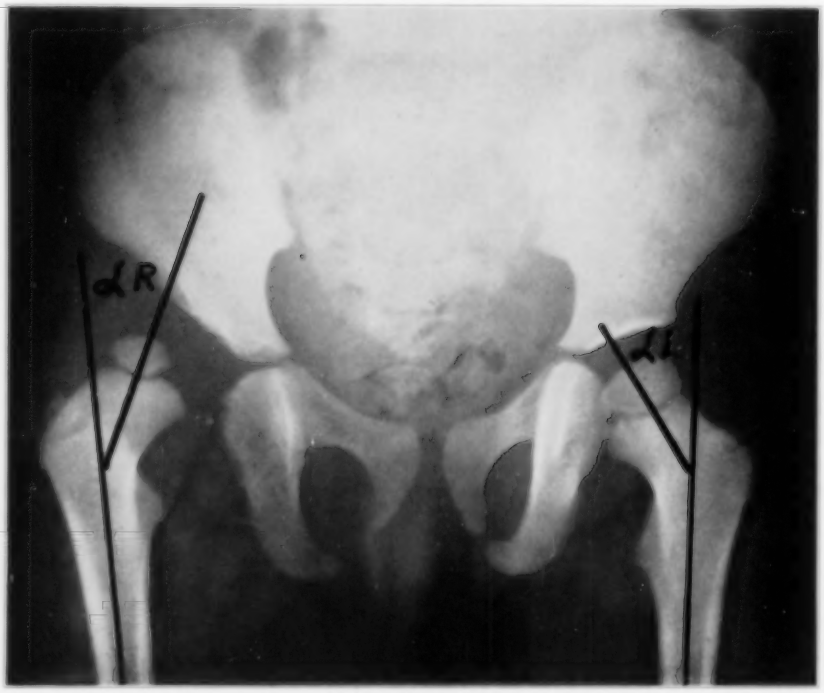


FIG. 16

Fig. 14: Anteroposterior and horizontal lateral roentgenograms of the model, with the angle $\beta'$ set at 23 degrees.
Fig. 15: Anteroposterior and horizontal lateral roentgenograms of the model, with the angle $\beta'$ set at 40 degrees.
Fig. 16: Anteroposterior and horizontal lateral roentgenograms of the model, with the angle $\beta'$ set at 60 degrees.




Figs. 17-A, 17-B, and 17-C: Roentgenograms of patient C.C., made on March 24, 1954.
Fig. 17-A: Anteroposterior roentgenogram, showing projected angles αR and αL.

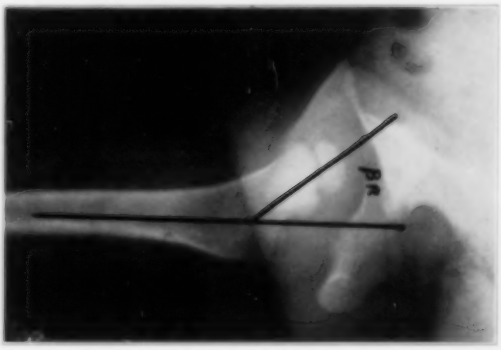



Fig. 17-B

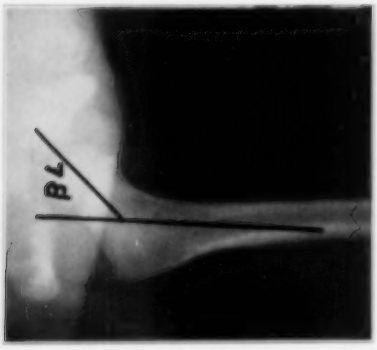



Fig. 17-C

Fig. 17-B: Horizontal lateral roentgenogram of right hip showing projected angle βR.
Fig. 17-C: Left horizontal lateral view showing projected angle βL.

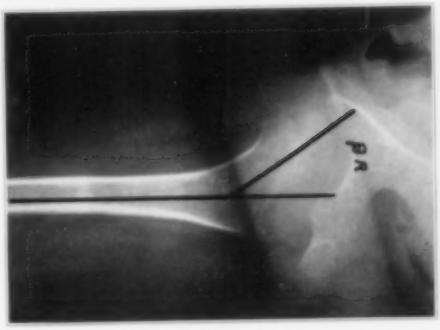
infancy up to the time of epiphyseal closure. It would be most interesting to be able to check this method against specimens of childrens' femora and pelves. Such material, however, is not available, and for this reason it was found necessary to use an adult femur for the demonstration described above.

## SUMMARY

It is universally recognized that the true angle of anteversion cannot be determined by any single roentgenographic exposure. Realization of this fact has led to the develop-

FIG. 18-A

Figs. 18-A, 18-B, and 18-C: Roentgenograms made on October 5, 1954.
Fig. 18-A: Anteroposterior view, showing projected angles αR and αL.



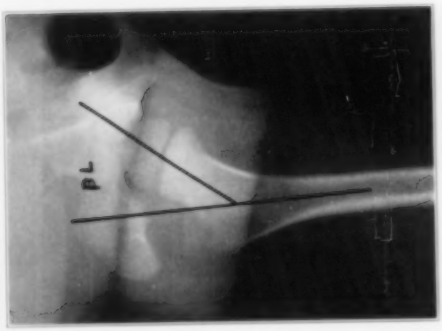




FIG. 18-B FIG. 18-C

Fig. 18-B: Right horizontal lateral view showing projected angle βR.
Fig. 18-C: Left horizontal lateral view showing projected angle βL.

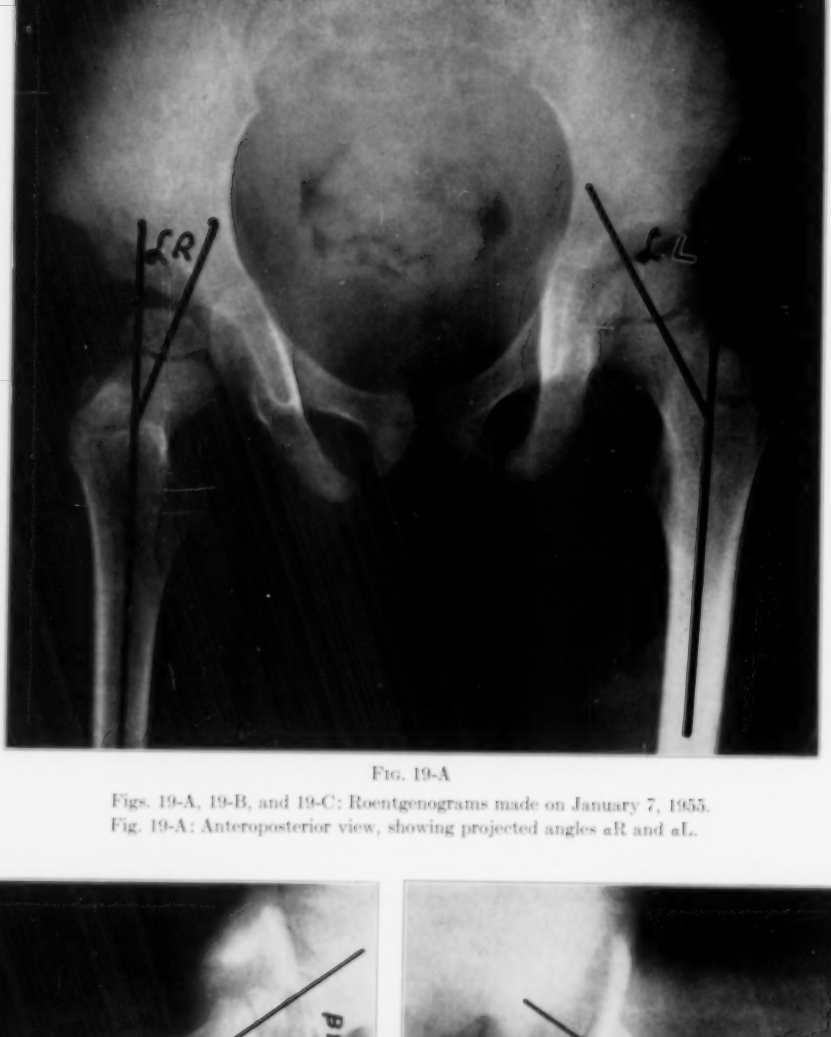



FIG. 19-A

Figs. 19-A, 19-B, and 19-C: Roentgenograms made on January 7, 1955.
Fig. 19-A: Anteroposterior view, showing projected angles αR and αL.







FIG. 19-B

FIG. 19-C

Fig. 19-B: Right horizontal lateral view showing projected angle βR.
Fig. 19-C: Left horizontal lateral view showing projected angle βL.

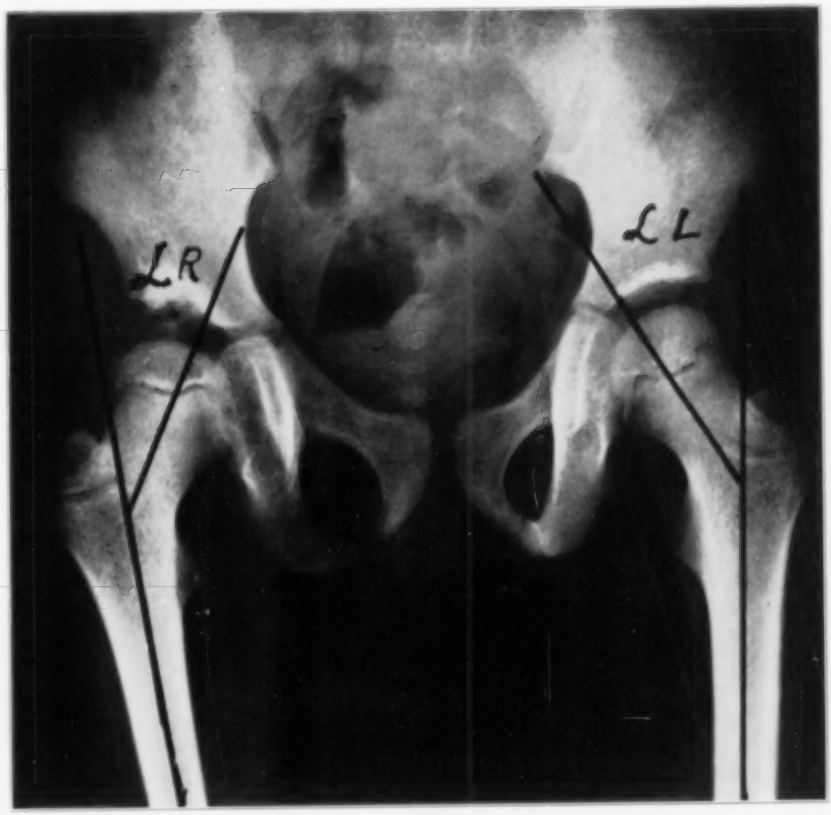



FIG. 20-A

Figs. 20-A, 20-B, and 20-C: Roentgenograms made on January 20, 1956.
Fig. 20-A: Anteroposterior view, showing projected angles αR and αL.

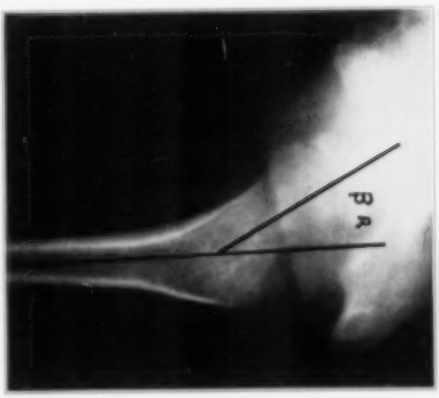



FIG. 20-B

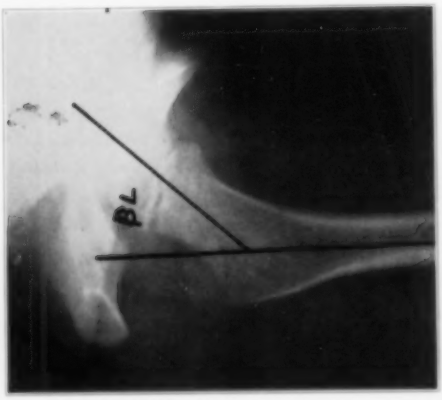



FIG. 20-C

Fig. 20-B: Right horizontal lateral view showing projected angle βR.
Fig. 20-C: Left horizontal lateral view showing projected angle βL.

ment of three other methods of calculating this angle [1, 2, 4]. All of these methods, together with our own, are basically similar. The essential requirement is that some variation of a lateral view be made, and from the projected angle thereon, the true angle is calculated by means of a mathematical formula. One of these methods uses only a single exposure. The other two require an anteroposterior view in addition to the modified lateral view. Comparison of our studies with those previously published would seem to indicate that accuracy is achieved to a similar degree by all four methods. As stated earlier, the chief merit of our method lies in the fact that the calculation is done from roentgenograms already made in order to determine the relationship of the femoral head to the acetabulum. In this way the patient will be spared additional radiation exposure, time will be conserved, and the need for extra equipment will be obviated.

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# A Two-Stage Stabilization Procedure for Correction of Calcaneocavus *

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The most disabling of all paralytic foot deformities is the calcaneocavus produced when functional power in the gastrocnemius and soleus is lost. Not only is gait severely affected, but marked deformity of the foot occurs if the muscle imbalance is not treated. The primary concern of all who treat such deformities should be to perform early adequate splinting and bracing, muscle-tendon transfers, and physiotherapy in order to minimize the bone deformity which occurs prior to the age at which foot stabilization can be performed. It is the purpose of this paper, however, to present an operative procedure for correction of calcaneocavus in feet in which advanced structural deformity has already developed.

The difficulties encountered in the surgical treatment of this condition can be inferred from a brief historical review. Whitman, in 1901, introduced the astragalectomy, now largely abandoned, with posterior displacement of the foot. In 1908, Robert Jones reported a two-stage mid-tarsal, subtalar, and ankle arthrodesis. Naughton Dunn, in 1919, reported a one-stage mid-tarsal and subtalar arthrodesis combined with transfer of the posterior tibial and peroneal tendons to the calcaneus. In 1934, Elmslie presented a technique which has recently been described in an article by Cholmeley. This consisted in a Steindler fascial stripping and an arthrodesis of the talonavicular joint. At the end of six-weeks' immobilization, a subtalar arthrodesis through a posterior approach is done in combination with posterior tendon transfers. Irwin, in a comprehensive article published in 1951, stated that little structural change occurs in the anteroposterior plane of the subtalar joint and recommended that a simple joint-cartilage excision be performed without the removal of a posterior wedge. He also stated, however, that this concept does not apply to patients who have walked for a number of years with untreated calcaneus feet.

It has been our experience at Shriners' Hospital, St. Louis Unit, that many calcaneocavus feet do exhibit deformity in the calcaneus and in the talocalcaneal joint. This deformity is due to the altered and imbalanced muscle tension which is exerted on the growing bone and is analogous in many respects to the alteration in the angle of the femoral neck which occurs in the presence of functional loss of the glutaeus medius. Sanchis Olmos pointed out that the abnormal relationship between the talus and calcaneus may be ascertained by measuring the talocalcaneal angle. To demonstrate bone deformity in the calcaneus itself we have made use of measurements of the tuber-calcanei angle. Palmer stated that there is a variation in the normal tuber-calcanei angle of from 10 to 40 degrees. In this study, thirty-five normal feet of children nine to fifteen years of age were x-rayed and the tuber angle was measured. A range of 22 to 45 degrees was noted, 33 degrees being the average. The measurement of the same angle in nineteen calcaneocavus feet revealed a range of 50 to 70 degrees, with an average of 61 degrees (Figs. 1-A and 1-B). This, we feel, demonstrates the presence of a calcaneus deformity and is the rationale for removing a posterior wedge from the talocalcaneal joint, the base of the wedge being directed posteriorly. By removing such a wedge of bone the calcaneus may be rotated from a more vertical position to a more horizontal position, a more normal length and contour in the heel being thereby restored. Considerable emphasis has been

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, February 1, 1956.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Calcaneocavus foot with a tuber angle of 62 degrees.
Fig. 1-B: Normal foot in the same patient with a tuber angle of 35 degrees.

placed in the past on shifting the foot posteriorly in order to obtain a longer posterior lever arm on which the power of the posterior tendon transfers may work. This, we feel, is not desirable from two standpoints: (1) in the presence of a total paralysis of the gastrocnemius and soleus, the length of the lever arm can seldom be increased sufficiently to raise the effective power of the tendon transfers to the level necessary for the body weight to be supported on the ball of the foot, and (2) the production of an overprominent heel leads to a poor appearance and to considerable difficulty in fitting the foot with normal shoes. We feel that the aim in the treatment of this deformity should be to obtain a stable foot which will be as nearly normal in appearance as possible and which will afford a good weight-bearing surface when fitted with ordinary shoes.

The facility by which a large wedge of the talocalcaneal joint can be excised through a posterior approach has been appreciated by others. Abbott performed the first such operation at Shriners' Hospital in 1927.

The two-stage operation was first performed by Crego, in 1948, and since that time twenty-seven feet have been stabilized in this manner.

FIG. 2

FIG. 3

Fig. 2: The talocalcaneal joint has been exposed, and the size of the wedge to be removed is indicated by dotted lines. The ankle joint is usually not opened.
Fig. 3: The talocalcaneal joint has been excised.

FIG. 4

FIG. 5

Fig. 4: This line drawing shows the talocalcaneal wedge to be removed, as viewed from the lateral aspect.

Fig. 5: When the gap is closed, the calcaneus is rotated to a more normal horizontal position. The fore part of the foot is now in a position of marked equinus.

## PROCEDURE

With the patient in the prone or lateral modified Sims' position, a three-inch incision along the medial border of the Achilles tendon is made proximally from the point of insertion. The tendon is retracted laterally and the incision is continued along the capsule of the subtalar joint and the superior surface of the calcaneus. The flexor hallucis longus is identified and retracted medially, the neurovascular bundle being protected. The posterior portion of the capsule is resected, and the superior aspect of the posterior tuberosity of the calcaneus denuded (Fig. 2). Two narrow-bladed, straight Crego retractors are then introduced alongside the joint, and a wide exposure is secured. The joint is next excised, the major portion of bone removed being taken from the calcaneus (Figs. 3 and 4). The size of the wedge is determined by a study of the preoperative roentgenograms. If a varus or valgus deformity co-exists, the shape of the wedge can be altered in order to correct these deformities. The gap is then closed by upward pressure being exerted on the heel. This rotates the calcaneus into a more horizontal position, which eliminates the necessity for elongating the heel by shifting the foot posteriorly. The fore part of the foot is, at this point, in a marked equinus position (Fig. 5). Cancellous-bone chips obtained from the removed bone are then packed into and about the remaining portion of the excised joint. Inasmuch as only one joint has been excised, stability is easily obtained. Desirable posterior tendon transfers to the calcaneus may also be done at this stage. Care must be taken, however, not to undermine too widely the skin flaps. Also, it is not wise to transfer anterior tendons through the interosseous space at this time. The incisions are closed loosely, and the extremity is immobilized in a long plaster cast.

The second stage is performed four weeks later. A plantar fasciotomy or Steindler stripping is done first. Following this, an incision is made on the dorsolateral aspect of the foot, overlying the sinus tarsi. The contents of the sinus tarsi are enucleated, the capsule and capsular ligaments are stripped from the head and neck of the talus, and the talonavicular joint is opened (Fig. 6). A wedge, with its base superior, is removed from this joint. Similarly, the calcaneocuboid joint is exposed and excised (Fig. 7). The gaps are then closed, the cavus and equinus deformities of the fore part of the foot being thus corrected. Any desirable anterior tendon transfers, including a Jones' suspension, may also be done at this time. The extremity is immobilized in a plaster cast for a period of six weeks.

FIG. 6

FIG. 7

Fig. 6: The talonavicular and calcaneocuboid joints have been exposed.

Fig. 7: This line drawing shows the relationship of the tarsal joints and the position of the foot following completion of the second stage. Note the position of the posterior tuberosity of the calcaneus. The heel prominence has been increased without the foot being shifted posteriorly.

Although tendon transfers are an integral part of the surgical correction of calcaneocavus, it is not the purpose of this paper to discuss the technique or results of such transfers. The results of tendon transfers in general are to be reported at a later date.

## POSTOPERATIVE CARE

Many of the complications of wound sloughs have been avoided by following a strict regimen in the postoperative period. Within one or two hours after each separate stage has been performed, a strip of plaster is cut from the cast and the sheet wadding is cut full length through to the skin. The edges of the cast are pried open to allow room for swelling, and the foot is elevated on pillows for twenty-four hours or longer. At the end of twenty-four hours the blood-soaked dressings are removed, the skin is cleansed with alcohol, and clean dry dressings are applied. At the end of ten days, the casts are removed and replaced with below-the-knee casts. If necessary, manipulation of the foot may be done at this time. The foot is immobilized for four weeks following the first stage and for six weeks following the second stage. After the second period of immobilization, the cast is removed and the extremity is bathed two or three times daily in warm water and mas-

FIG. 8

A foot in which a major complication occurred. Extensive scarring is seen about the foot and ankle.

FIG. 9-A

FIG. 9-B

Figs. 9-A and 9-B: Case 1. Preoperative and postoperative roentgenograms.
Fig. 9-C: Postoperative photograph of the foot.

saged lightly with oil. Active assistive exercises of the joints and tendon transfers are started. Weight-bearing is started as soon as pain and swelling will allow. Postoperative bracing is usually not used unless specifically called for.

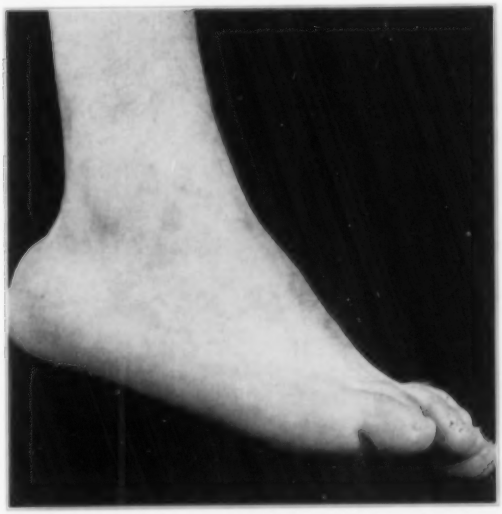

FIG. 9-C

### COMPLICATIONS

Two minor and one major complications occurred. The two minor complications consisted of mild maceration of the skin edges of the first-stage incision, resulting in a two-week delay in the performance of the second stage. The major complication was a large full-thickness skin slough about the ankle and over the dorsum of the foot, necessitating a skin graft and a one-year delay in the performance of the second stage (Fig. 8). This complication was the result of improper postoperative care and emphasizes the absolute necessity of opening the cast to allow for swelling in the immediate postoperative period. There were no wound infections.

### RESULTS

Twenty-four of the twenty-seven feet were available for evaluation. Seventeen were examined by the authors. The average length of the postoperative follow-up was two and three-quarters years. Because of the small number of cases and because of the short postoperative period, no statistical analysis was attempted, and this paper is to be considered a preliminary report.

Early results were classified as satisfactory (1) if the deformity had been corrected and the heel length restored, (2) if solid, painless fusion of all three joints had been obtained, and (3) if the foot could be fitted with normal shoes. If these criteria were not met, the result was considered unsatisfactory. On this basis the results in twenty-one feet were satisfactory and the results in three were unsatisfactory. Of the three feet with unsatisfactory results, two had been arthrodesed in a varus position which necessitated restabilization. The third foot was the only one in which satisfactory correction of the calcaneus deformity had not been obtained. In none has a recurrence of the calcaneus deformity developed to date.

In no case was there failure to obtain solid fusion of any of the wedged joints. Pain

FIG. 10-A

FIG. 10-B

Figs. 10-A and 10-B: Case 2. Preoperative and posteroperative roentgenograms.

Fig. 10-C: Postoperative photograph of the foot.

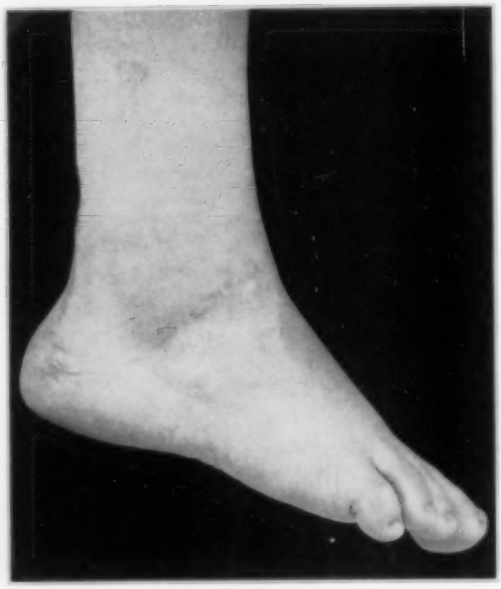

FIG. 10-C

was not a preoperative factor, nor was there any complaint of late postoperative pain in the foot or ankle. All of the brace-free children who were examined stated that their gait had been improved. This was true in spite of the fact that only one patient, with bilateral calcaneus deformity, could walk on the balls of her feet.

All the children were wearing conventional shoes, and none complained that shoe fitting presented any difficulty aside from the problem of obtaining mismated shoes. A number stated that prior to surgery they were required to wear high-top shoes because the lack of the heel prominence allowed a low-quarter shoe to slip from the foot; that difficulty had been eliminated (Figs. 9-A through 10-C).

## CONCLUSIONS

1. Advanced calcaneocavus includes structural bone changes in the calcaneus, as evidenced by an increase in the tuber angle.

2. The objective in the treatment of calcaneocavus is to obtain a corrected, stable foot which is as nearly normal in appearance as possible and which will afford a good weight-bearing surface when fitted with a normal shoe.

3. Shifting the foot posteriorly in order to obtain a long posterior lever arm is felt to be unsound and undesirable if a secondary foot deformity is thereby produced.

4. The two-stage operative procedure for stabilization of the calcaneocavus foot which has been presented facilitates the removal of a posterior bone wedge from the subtalar joint, allowing rotation of the calcaneus to a horizontal position and restoring heel length.

5. Immediate postoperative care is necessary in order to minimize complications due to pressure within the cast.

6. In a preliminary survey it was found that the objectives of the operation were obtained in twenty-one of the twenty-four feet available for evaluation.

7. A major complication occurred in only one case. There were no infections.

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## DISCUSSION

Dr. C. E. Irwin, Atlanta, Georgia: Before discussing the interesting paper presented by Dr. Crego and Dr. Scheer, I would like to make a few remarks about my conception of the gross pathology of the calcaneus foot. Two important changes in the joint relationship occur. First, the posterior part of the foot, including the talus and calcaneus, is forced into dorsiflexion. This abnormal movement takes place in the ankle joint, not in the subtalar joint. The two bones move together as a unit. The posterior part of the foot is maintained in this dorsiflexed position by the action of the unopposed extrinsic extensors on the anterior aspect of the foot and ankle. Second, the anterior part of the foot is forced counterwise into an abnormal degree of plantar flexion. This abnormal movement takes place in the mid-tarsal joints. The resulting cavus deformity is maintained due to the action of the contracted plantar fascia and the unopposed short toe flexors.

The object of the surgical treatment, regardless of the method used, is: first, to overcome the increased dorsiflexion of the posterior part of the foot at the ankle joint. This will return the calcaneus to a more horizontal position and will restore the normal projection of the heel posteriorly. The second object is to increase the length of the plantar surface of the foot and to shorten the dorsum of the foot.

I would like to present a simple method of obtaining these objectives without doing a two-stage procedure. First, the increased dorsiflexion in the posterior part of the foot can be overcome by plantar flexing the entire foot at the ankle. In order to maintain this position one or more of the tendons which are acting as deforming factors must be transferred to the calcaneus. This will restore the proper relationship between the talus and tibia and will maintain the desired projection of the calcaneus posteriorly. To overcome the increased equinus deformity of the fore part of the foot, the plantar surface must be lengthened and the dorsum shortened. This can be done by plantar fasciotomy and removal of a wedge of bone from the mid-tarsal joints, the base of this wedge pointing toward the dorsum of the foot.

In extreme cases the talus and calcaneus can be maintained in a plantar-flexed position by inserting a Steinmann pin in the plantar surface of the foot, up through the calcaneus into the body of the talus, and by having an assistant pull posteriorly while the leg, ankle, and posterior portion of the foot are immobilized in plaster. When this part of the cast has been allowed to set, the anterior portion of the foot can be dorsiflexed and the cast completed. If additional correction of the equinus deformity of the fore part of the foot is desired, the pin can be left in place and the fore part of the foot wedged every second or third day.

I routinely supply these patients, especially children, with a long walking splint to which an elastic strap has been attached posteriorly in order to protect the transfers. The long splint will prevent the development of recurvatum in a growing child.

The authors state they have stabilized twenty-seven calcaneus feet by the two-stage method since 1948. Apparently, this is their routine operative procedure for the correction of calcaneus feet.

I agree that it is not necessary to attempt to displace the foot posteriorly at the subtalar joint, but I do not agree that all calcaneus feet need to be corrected by the two-stage method, as presented by the authors. In my opinion the vast majority of calcaneus feet can be returned to a good weight-bearing position on which an ordinary shoe can be fitted and have a good appearance without the excision of a wedge of bone from the posterior portion of the subtalar joint.

Dr. David S. Grice, Boston, Massachusetts: Dr. Scheer and Dr. Crego have presented a method for correction of severe calcaneus feet by means of which, as the illustrations demonstrate, excellent results have been obtained. I have had no experience with this method since we rarely see this severe degree of calcaneus. Our experience has been that early tendon transplantation will prevent the development of such severe deformities and that extra-articular fusion is very satisfactory in the treatment of the young child with a moderate deformity. I am sure the authors would agree that the mild or moderate calcaneus deformity

*(Continued on page 1264)*

# Serum-Proteolytic-Enzyme Inhibitors in Bone Diseases

## A Clinical Laboratory Method of Aid in Evaluating Disease Activity

BY RICHARD H. HALL, M.D., AND FRANK W. ELLIS, M.D., LONG BEACH, CALIFORNIA

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In the daily clinical management of certain diseases, there are instances in which one would welcome an objective laboratory means of assessing both the activity of the disease process and the responsiveness of the host to treatment, or, as it has been called, the factor of "host resistance". Particularly in such conditions as tuberculous osteomyelitis, rheumatoid arthritis, and primary bone tumors, our usual methods of roentgenographic examination, hematological study, sedimentation-rate measurement, and blood-chemistry determination may fail to reveal the true clinical status of the patient.

Previous investigators have found that certain inhibitors of serum proteolytic enzymes fluctuate widely in many diseases [4]. In particular the inhibitors of serum chymotrypsin and rennin have been studied in great detail, especially as regards their application to the clinical study of neoplasms [1, 5, 6]. Methods of measuring these inhibitors have been described in the literature [4]. Briefly, the inhibitor of chymotrypsin has been shown to be sensitively correlated to disease activity, whereas the inhibitor of rennin or pepsin has been found to be an index of "host resistance". Serial determinations of these two substances have proved to be a sensitive guide to the management and prognosis of several diseases.

A trial study of the use of these measurements in the treatment of several orthopaedic diseases was undertaken at the Long Beach Veterans Administration Hospital, as an extension of the previous five-year study of their use in the treatment of neoplastic diseases at this same institution. It is the purpose of this paper to report our experience to date.

The inhibitors of the enzymes chymotrypsin and rennin are definite organic compounds, probably proteins, occurring in large amounts in the circulating blood. They have not been isolated but are known to be highly specific inactivators of their respective enzymes, as are the better known inhibitors of pepsin and trypsin (isolated by Herriott and by Kunitz and Northrop). Normally a delicate and constant balance is maintained between the rennin and chymotrypsin inhibitors, but in metabolic disturbances, especially those caused by cancer, inflammations, and pregnancy, profound changes occur.

The essential feature of the proteolytic-enzyme pattern in the blood of healthy subjects is an excess of rennin inhibitor over chymotrypsin inhibitor. The usual values in adults are from eight to twelve units of the former and from three to five units of the latter. Children, adolescents, and young adults normally show a very high rennin-inhibitor level, frequently from sixty to ninety units. An occasional adult with no apparent disease or abnormality may maintain an elevated rennin-inhibitor level throughout his lifetime. There is no corresponding variation in chymotrypsin-inhibitor concentrations, the same narrow range of values being normal for all ages.

Since 1952 measurements of the proteolytic-enzyme inhibitors have been made in approximately 100 orthopaedic patients. The cases selected have been almost exclusively cases of chronic infectious diseases (primarily tuberculosis), suspected malignant tumors, and rheumatoid arthritis (Table I). The following case histories indicate the several fields of clinical application and usefulness of these methods.

TABLE I

| Final Diagnosis | | No. of Cases | Enzyme Pattern |
|---|---|---|---|
| Tumors: | | | |
| Chondrosarcoma | | 3 | Confirmed malignant growth |
| Fibrosarcoma | | 3 | Confirmed malignant growth |
| Metastatic malignant growth | | 6 | Varied |
| Osteogenic sarcoma | | 4 | Confirmed malignant growth |
| Rhabdomyosarcoma | | 2 | Confirmed malignant growth |
| Reticulum-cell sarcoma | | 1 | Pattern shadowed by surgery, diagnosis not confirmed |
| Benign tumors | | 9 | Benign growth confirmed |
| | Total | 28 | |
| Arthritis: | | | |
| Marie-Strümpell disease | | 19 | Apparently reflected clinical response to disease activity |
| Rheumatoid arthritis | | 12 | Apparently reflected clinical response to disease activity |
| Degenerative arthritis | | 6 | Normal |
| | Total | 37 | |
| Osteomyelitis: | | | |
| Mixed, non-isolated, or non-specific osteomyelitis | | 13 | Apparently reflected disease activity |
| Tuberculous osteomyelitis | | 24 | Apparently reflected disease activity |
| | Total | 37 | |
| Miscellaneous: | | | |
| Coccidioidomycosis | | 2 | Normal |
| Eosinophilic granuloma | | 1 | See Fig. 5 |
| Paget's disease | | 1 | Confirmed presence of active disease |
| Syphilis (Charcot's knees) | | 1 | Normal |
| | Total | 5 | |
| Grand Total | | 107 | |

## CASE REPORTS

CASE 1. A man, forty-five years old, was transferred to the Long Beach Veterans Administration Hospital, June 16, 1952, for treatment of active pulmonary tuberculosis and traumatic arthritis of the left hip due to old fracture. He had fallen from a haystack at the age of eight years, injuring the hip. He had been drafted into the Army on July 22, 1942, despite the fact that he limped but had been given a disability discharge in 1943 because of aggravation of the hip condition as a result of marching. After June 1951, the hip condition had gradually worsened until finally it had become completely disabling. He had entered a hospital in October 1951 and had been treated with traction and immobilization without much relief.

At the Veterans Hospital a "coin lesion" in the left lung was found and diagnosed tentatively as tuberculosis. Sputum cultures were subsequently found negative, however, and no malignant cells were found in studies of bronchial washings. The lesion in the lung was asymptomatic, and the patient refused excision biopsy for diagnostic purposes. He was accordingly transferred to the Orthopaedic Service of the Veterans Hospital on August 15, 1952, for treatment of his hip condition.

At the first consultation in July 1952 the only positive physical findings observed were those in the left hip. In this region he had swelling, some deep fluctuation, and much tenderness anteriorly, laterally, and posteriorly. There was at least two inches of shortening of the left femur, with protrusion of the upper end along the ilium. He was unable to walk as a result of the pain caused by motion and weight-bearing.

A chest roentgenogram made July 22, 1952, showed a "coin lesion" in the central portion of the left lung and flattening of the right side of the diaphragm with obliteration of the right costophrenic angle.

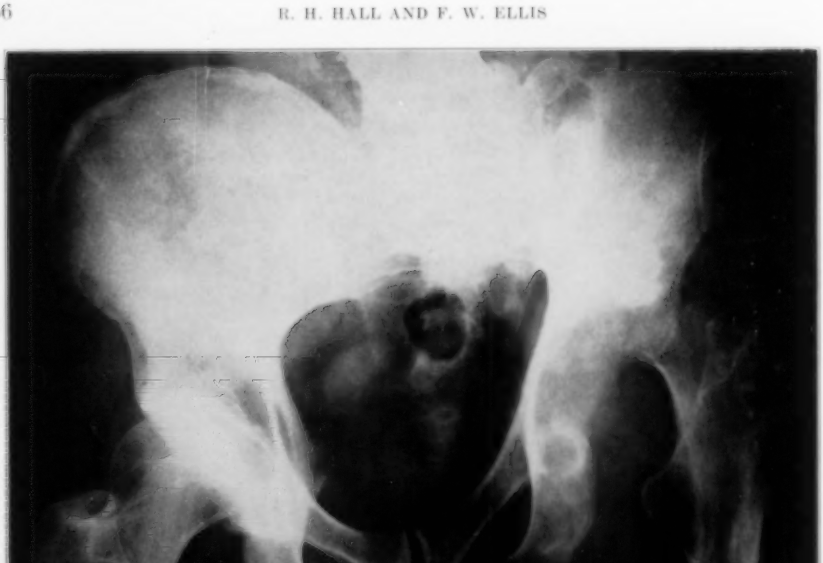

FIG. 1-A

Case 1. Roentgenogram, made before treatment was instituted, showing destruction of the left hip as a result of tuberculosis.

Roentgenograms of the left hip made June 24, 1952 (Fig. 1-A) showed absence of the head and of part of the neck of the left femur with dislocation of the shaft and the remaining portion of the neck superiorly. The acetabular roof and trabeculations were not discernible. Disuse was suggested by spotty demineralization of the femur.

Serological tests for syphilis were slightly positive. The sedimentation rate was normal one time and slightly elevated another. The number of white blood cells was normal in the total count, with the presence of five eosinophils being the only abnormal finding in the differential count. Red corpuscles and hemoglobin were at normal levels. Seven examinations of gastric washings, made by means of smears and cultures, revealed no acid-fast bacilli. No ova or parasites were found in the stools. The left hip joint was aspirated on July 18, 1952. A smear of the aspirated material was negative for acid-fast bacilli and spirochetes, and cultures were negative for routine organisms and fungi. A biopsy excision, August 21, 1952, established the diagnosis of tuberculosis. Caseating epithelioid tubercles were seen in an area of chronic synovitis in the left hip. Smears and cultures were positive for acid-fast bacilli.

The patient was immobilized in a spica cast for three months and was treated with streptomycin and para-aminosalicylic acid until August 1954. The wound healed primarily postoperatively, and when he was last seen, there was no swelling in his hip. He had been furnished with a two-inch elevation on the left shoe and could walk with a cane for one or two blocks without symptoms. His disease was clinically arrested. Fatigue and pain arose after walking about three blocks. A roentgenogram made August 20, 1953, showed the margins of the left femoral neck to be more sharp and clear, although dislocation was still present. Spotty demineralization had lessened.

At the present time we feel that studies of the enzyme pattern are of great value in the follow-up of patients with bone and joint tuberculosis. When no cultures can be obtained, the enzyme pattern gives an index of the remaining disease activity (Fig. 1-B). In this patient the enzyme pattern took over two years to return to normal even though no sinuses were present and medication was continuous. When he was last seen, the pattern had not reversed since medication had been discontinued. Accordingly, we felt the disease was probably arrested.

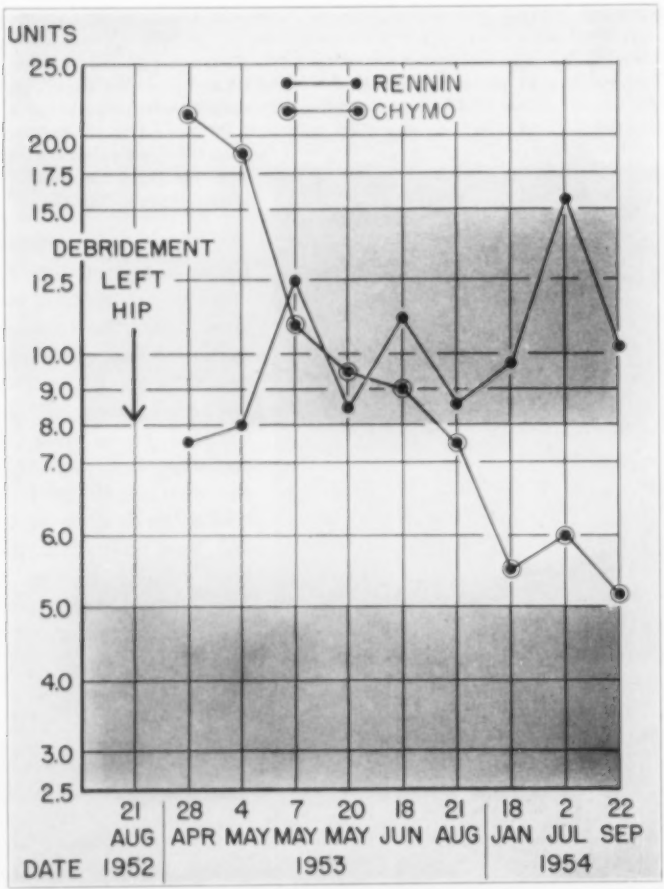


FIG. 1-B

The enzyme pattern was abnormal in early 1953. It returned to normal after débridement had been done and after medication had been continued for two years, starting in August 1952.

CASE 2. A white female, twenty-five years old, was admitted to the Orthopaedic Service on February 13, 1950, with a complaint of pain in the right hip. This pain, which had been present since October 1949, was referred to the knee, was not related to exercise or exertion, was continuous even at night, and was becoming increasingly severe. Except for general obesity, no positive findings were revealed by physical examination at the time of admission.

The only finding revealed by skeletal roentgenograms was an osteolytic lesion in the right hip (Fig. 2-A). Roentgenographic examination of the chest gave negative results, and all laboratory tests were also negative, except for an increase in the sedimentation rate. A report of the enzyme pattern was not obtained on admission. A biopsy of the osteolytic lesion March 3, 1950, revealed that the neoplasm was an osteogenic sarcoma (Fig. 2-B). Accordingly a hemipelvectomy was done on the right side March 14, 1950. Postoperatively she became an asymptomatic wheel-chair patient and left the hospital after her wound had healed. She had no further trouble until the summer of 1951, when she caught a "head cold" which she could not shake. Studies of the enzyme pattern (Fig. 2-C) revealed values compatible with low-grade disease activity. A chest roentgenogram February 18, 1952, showed a round density, consistent with a metastatic focus, in the lower hilus of the right lung. A lobectomy of the lung was done March 10, 1952, the entire middle lobe and a segment of the upper lobe being resected. Microscopic study of pulmonary sections revealed an undifferentiated sarcoma.

The postoperative course was uneventful, and she was clinically asymptomatic until August 1952, when she started having aching sensations in both shoulders, elbows, wrists, and hands. By September

the enzyme pattern had reversed, and clinically the symptoms were becoming more severe. On October 6, 1953, she was readmitted and a thorough search for possible further metastases was carried out. None were found. On October 29, 1953, a new diagnosis was established—rheumatoid arthritis. Cortisone was started November 6, 1953, resulting in complete remission of symptoms. Good control of the symptoms was maintained most of the time thereafter. The findings of chest roentgenograms and of clinical studies were negative except for postoperative changes. In November 1955, more than five years after the amputation and more than three years after the pulmonary resection, the patient was still living and was relatively asymptomatic.

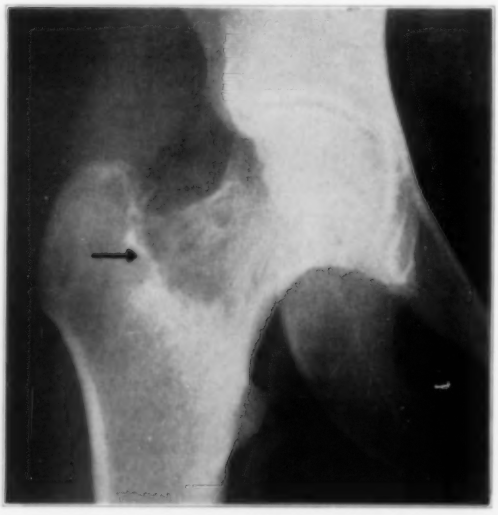

FIG. 2-A

Fig. 2-A: Case 2. Roentgenogram, made at the time of admission, showing an osteolytic lesion in the right hip.

This case exhibited the confusing picture of three entities. The original sarcoma was removed surgically, and the pulmonary metastases were later also removed. Subsequently the patient was found to have rheumatoid arthritis. She responded fairly well clinically to cortisone, but there often was an elevation in the chymotrypsin-inhibitor level when the medication had been omitted or the dose had been inadequate (Fig. 2-C). There was a remission, due presumably to

FIG. 2-B

Photomicrograph (× 120) showing the bizarre pleomorphic pattern presented by the osteogenic sarcoma.

pregnancy, for seven months in 1954 and 1955, but a spontaneous abortion terminated the remission and she had to return to steroid therapy. When last seen in November 1955, she was reasonably comfortable. Her joint symptoms were being controlled medically and there was no clinical evidence of malignant growth.

Case 3. A former sailor, twenty-one years old, was admitted August 2, 1954, with a chief complaint of a painful stiff neck of about two months' duration. He had first noted joint symptoms consisting of aches in his knees, hips, and elbows about two and one-half years previously while serving aboard ship in the Navy. In a base hospital in Yokosuka, Japan, early in 1952, roentgenograms had revealed a spot in the lower portion of the right femur near the knee joint. A biopsy excision had been done, and the patient had been told he had fibrous dysplasia. After recovering from surgery, he had returned to full duty and had had no further trouble

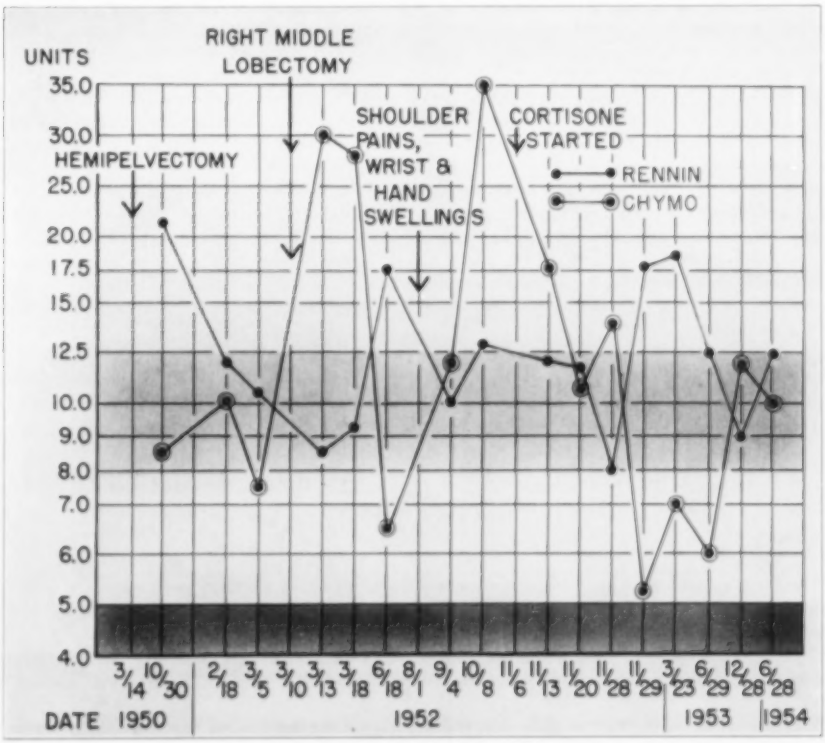


Fig. 2-C

The enzyme pattern exhibited catabolic activity, first as a result of the malignant growth and latter as a result of rheumatoid arthritis.

until late in 1953, when he had had an episode of a stiff neck for two or three days; this had not been disabling and had seemed to subside following the usual sick-bay treatment of heat, aspirin, and massage. The episode of neck pain that brought him to the Veterans Hospital had started insidiously about a month after he had been discharged from active duty and had become gradually worse. It was aggravated by using or moving his neck, was relieved by rest, and was not intolerable unless he did heavy physical activity.

Physical examination revealed a slender male in no acute distress. He had mild tenderness of the cervical soft tissues when deep pressure was applied and some obvious discomfort when he moved his neck. He splinted his neck voluntarily. Other findings were normal.

A pulmonary roentgenogram July 27, 1954, revealed an irregular mottled area of decreased density in the anterior end of the left seventh rib. Roentgenograms of the cervical spine made on the same day showed a loss of normal bone texture in the body of the fifth cervical vertebra, with numerous confluent radiolucent areas and a slight degree of expansion anteriorly. In addition there was narrowing of the intervertebral disc space between the fourth and fifth cervical vertebrae. The leukocyte count was 11,700 per cubic millimeter, 74 per cent of the cells being neutrophils; the red-corpuscle count, the hemoglobin, and the findings of the

urinalysis were normal. The erythrocyte sedimentation rate (Wintrobe) was thirty-one millimeters in one hour. The enzyme pattern on August 9, 1954, indicated disease activity, the value for the chymotrypsin inhibitor being 10.5 and that for the rennin inhibitor being 14.7. The values for serum calcium, phosphorus, alkaline phosphatase, cholesterol, and total protein and the ratio of albumin to globulin were all found to be within normal limits on two separate occasions. The lesion resulting from the biopsy in the right femur apparently was completely healed.

Upon transfer of the patient to the Orthopaedic Section on August 9, 1954, a biopsy excision was done in the diseased area of the left seventh rib. A cervicothoracic cast was applied. Slides of tissue previously removed from the knee area were requested from the Navy. After study of material from the rib lesion grossly and microscopically, the Pathology Department made the diagnoses of "(1) eosinophilic granuloma of bone, (2) myelofibrosis, etiology undetermined". The slides received from the Navy revealed only myelofibrosis. Upon presentation of the case to the tumor board and to the orthopaedic consultant and attending staff, it was felt by all concerned that the man had eosinophilic granuloma. A needle biopsy of the cervical lesion was recommended, together with cultures for all known bacterial, fungoidal, and viral pathogens. The biopsy was to be followed immediately by intensive penicillin and wide-spectrum antibiotic therapy as well as by radiation therapy.

On September 30, the plaster was bivalved and a needle biopsy was performed. The cultures were all negative, and the microscopic sections revealed only myelofibrosis. He received antibiotic therapy for one week. Between September 30 and November 11, 1954, 1500 roentgens were applied to the right side of the cervical spine through a portal seven by seven centimeters in size (factors: 250 kilovolts; filtration, copper 0.5 millimeter in thickness; half-value layer, copper 1.7 millimeters in thickness).

Clinically the neck symptoms subsided gradually. Eventually he became asymptomatic and was able to walk while wearing a Minerva jacket; in February 1955, the fixation apparatus was removed. Roentgenograms showed solid bone fusion of the fourth and fifth cervical vertebrae and apparent healing of the diseased area in the fifth cervical vertebra. He was discharged, having received the maximum hospital benefit, on March 16, 1955. When last seen in the Out-Patient Department in September 1955, he was feeling well and working full time.

This patient with an eosinophilic granuloma which had nearly destroyed the body of the fifth cervical vertebra showed a typical enzymatic response to subsiding disease activity (Fig. 3). As the healing progressed (as shown by roentgenograms), the enzyme pattern gradually returned to normal and the patient's symptoms subsided. When the enzyme pattern was normal and the patient was asymptomatic, the plaster spica was discontinued. We feel that the enzyme pattern might be of use as a means of determining the end point for therapy. This possible usage is being investigated further.

Case 4. A colored veteran, thirty-three years old, was admitted for the fourth time with pulmonary tuberculosis on November 9, 1953. At this time he was complaining primarily of back pain, and the pulmonary disease was thought to be arrested.

Physical examination revealed a well nourished male who did not appear acutely ill. There appeared to be a very slight tendency toward kyphosis at the level of the first lumbar vertebra. Otherwise findings were normal.

Roentgenograms of the lumbar spine showed narrowing of the first lumbar interspace and a destructive process involving the surfaces of the adjacent first and second lumbar vertebrae. Psoas shadows were not visualized. No acid-fast organisms were observed in direct, culture, and guinea-pig studies of material obtained by repeated gastric washings. Erythrocyte sedimentation rates (Wintrobe) varied from eight to thirty millimeters in one hour. A study of the enzyme pattern made July 12, 1954, revealed a chymotrypsin-inhibitor level of 6.2 and a rennin-inhibitor level of 7.2, indicating the presence of some disease activity.

He was again started on a tuberculosis regimen, one gram of streptomycin being given semi-weekly and twelve grams of para-aminosalicylic acid and 300 milligrams of isoniazid being given daily. Bed rest was maintained with the patient in a plaster spica. On August 10, 1954, an excision of the psoas abscess was done together with complete débridement of the diseased twelfth thoracic and first and second lumbar bodies. The surgically created cavities were then packed with bone millings. The patient recovered rapidly from surgery, his wound healing primarily. Cultures were negative, but pathological sections showed epithelioid tubercles with caseation. On October 26, 1954, a posterior-element arthrodesis of the involved vertebrae was done. Again the patient recovered uneventfully. He became ambulatory after the fusion was deemed solid and was discharged on tuberculotic drug therapy in December 1954. When last seen in the Out-Patient Department in January 1956, he was asymptomatic and working full time as a post office employee.

Inasmuch as in years past the pulmonary cultures had been positive, the findings of pathological sections of diseased tissue from the spine had been consistent with tuber-

culosis, and cultures of diseased tissue had been negative for fungi and other pathogens, this case was included with those of proved tuberculosis of the spine. We realize that our acceptance of this diagnosis is subject to some criticism, but a dubious diagnosis is often the best we can obtain after extensive antibiotic therapy. Continued clinical quiescence of the disease activity paralleled the return of a normal enzyme pattern (Fig. 4). The making of a final judgment as to arrest would obviously be premature at this time.

Case 5. A white veteran, thirty-four years old, was admitted to the Orthopaedic Service February 5, 1954, complaining of progressively increasing back pain. This pain had developed following a posterior-element fusion of the tenth thoracic to the first lumbar vertebra, performed for presumed tuberculosis in 1949.

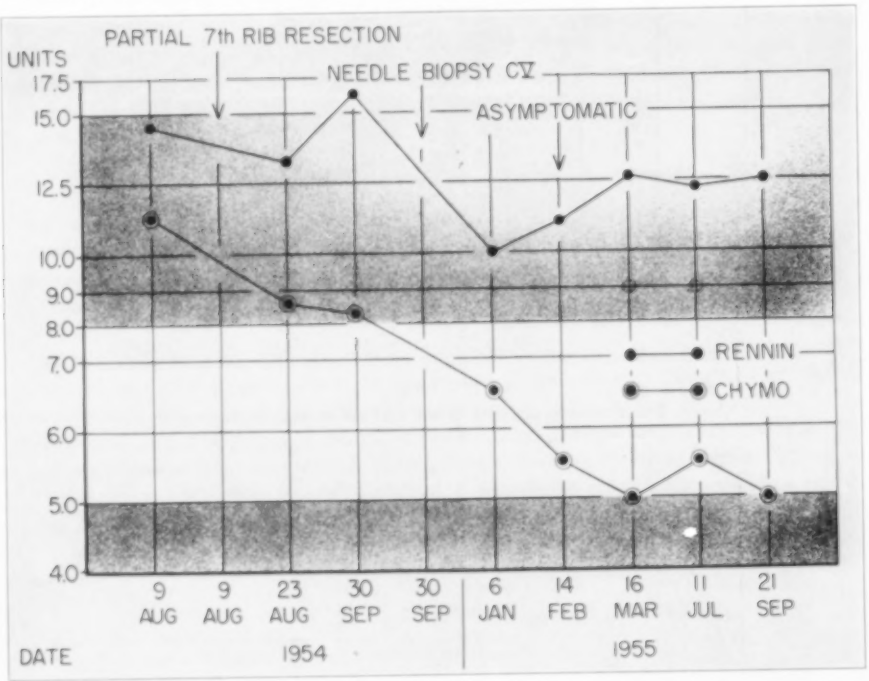


Fig. 3

Case 3. Eosinophilic granuloma.

Following the fusion operation he had felt better for about a year, but then the symptoms had become gradually and steadily worse. At admission the pain was unbearable and could not be relieved by anything short of heavy narcotic medication. He had some radiation of pain into the lumbar area, the buttocks, and the thighs, but no weakness or paraesthesia and no bladder or bowel symptoms.

The findings of physical examination, February 6, 1954, were essentially normal, except for a well healed mid-line surgical scar over the lower thoracic spine. Neurological consultation revealed no demonstrable involvement of any cranial or peripheral nerves.

Anteroposterior and lateral roentgenograms (made with the patient bending) and planigrams of the thoracic spine showed the posterior-element fusion to be apparently solid. No sequestration was visualized. The findings of a pulmonary roentgenogram were negative. Although the values for the sedimentation rate and blood count were normal and the findings of serological tests for syphilis were negative, the enzyme pattern was reversed, the chymotrypsin inhibitor being 12.5 units and the rennin inhibitor, seven units (Fig. 5). The spinal-fluid examination revealed normal hydrodynamics and chemistry values, and no organisms were seen in the smears or grown in the cultures.

Treatment included bed rest, the application of a plaster spica, and drug therapy (one gram of streptomycin semi-weekly and twelve grams of para-aminosalicylic acid daily). The patient's symptoms continued with occasional acute exacerbations but with gradual over-all improvement. Approximately a year after admission his symptoms were completely gone. On February 8, 1955, he was taken to surgery and through

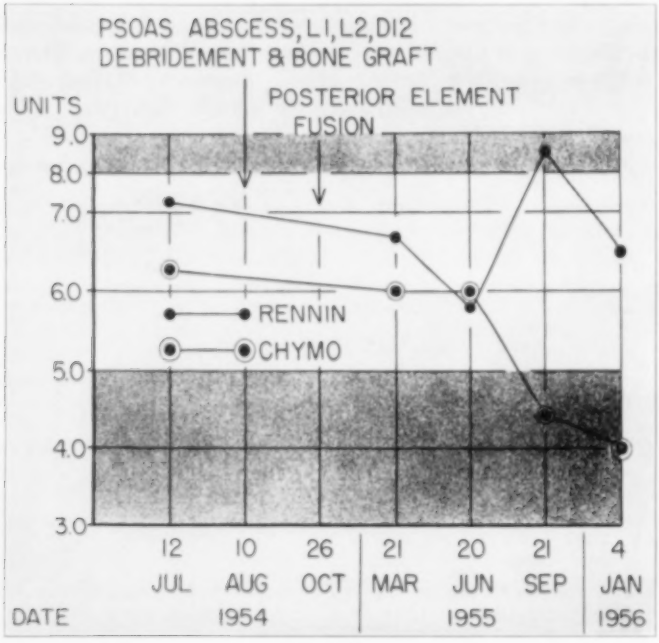


FIG. 4

Case 4. Tuberculous spondylitis of the first and second lumbar vertebrae.

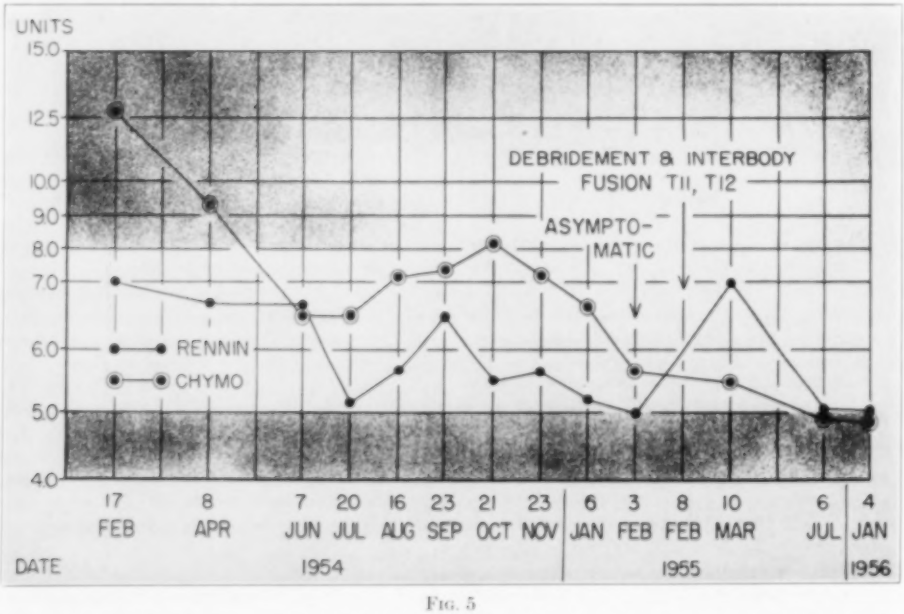


FIG. 5

Case 5. Non-tuberculous spondylitis of the eleventh and twelfth thoracic and the first lumbar vertebrae.

a retroperitoneal and transdiaphragmatic approach the eleventh and twelfth thoracic interspaces were debrided. Grossly no tuberculous tissue was found. Culture material was nevertheless taken, the results of the cultures being later reported as negative. Surgical specimens studied microscopically showed only non-specific inflammatory reaction, non-tuberculous in appearance. The eleventh thoracic interspace was found bridged by solid bone anteriorly and the twelfth thoracic interspace was filled with homologous bone-graft granules. Postoperatively the patient's recovery was uneventful. The bone graft was apparently gradually demineralized and later was replaced by solid bone. He became asymptomatic and ambulatory and was discharged, having received maximum hospital benefit, May 5, 1955. He was seen in the follow-up Clinic January 4, 1956, at which time he was working and asymptomatic and had gained thirty pounds. The chymotrypsin-inhibitor level was normal, indicating that no disease activity was present.

This man was treated for tuberculosis until the diagnosis was proved to be otherwise. His course could perhaps have been considerably shortened had we known the correct diagnosis on admission. Needle biopsy might have been considered earlier, but even when abundant material was obtained from extensive curettage, the amount of inflammatory tissue found was relatively small. Our needle biopsies so far have been disappointingly inadequate.

## DISCUSSION

Our experience in using the proteolytic-enzyme-inhibitor determinations on the Orthopaedic Service has paralleled the findings previously obtained in cases of neoplastic diseases and of pulmonary tuberculosis.

In cases of bone infection, such as osteomyelitis of the spine, study of the enzyme pattern seems most valuable. We have had several cases in which solid posterior-element spine fusions were done for tuberculosis or for osteomyelitis of undetermined etiology, the suspected cause being tuberculosis. In these cases there is often a low-grade or normal temperature, a slightly elevated or normal sedimentation rate, and no diagnostic or helpful physical findings. The patients complain of pain, and in some institutions they might be called malingerers. The enzyme-inhibitor patterns have been most helpful. The patterns, abnormal on admission, return to normal, the patients' complaints subsiding simultaneously. With tuberculosis the changes toward normal occur more rapidly when antibiotic therapy is used. In cases of osteomyelitis in which tuberculosis is suspected, but mixed organisms are later found or in cases in which no organisms can be demonstrated, tuberculous antibiotics have not noticeably helped. It sometimes takes a year or more for the symptoms to disappear and for the enzyme pattern to return to normal.

In cases of bone tumors of the osteo-chondro-fibro-blastic series the enzyme patterns thus far produced have shown reversal (that is, chymotrypsin inhibitor in excess of rennin inhibitor) when the tumor was malignant and have shown no change when it was benign. After surgical removal of a primary malignant bone tumor, the pattern returns to normal in a few weeks and may remain normal for many months or years. Reversal may then occur. This reversal may either precede or follow the clinical discovery of the development of metastases, but it has always been found significant of some disease activity. When enzyme studies as well as chest roentgenograms are included in the postoperative follow-up of patients with tumors, it is our impression that metastases may be drawn to our attention sooner than they would be if roentgenograms alone were used. The reason for this may be that the metastatic lesion is occasionally overlooked in the original interpretation of the routine roentgenogram.

At times the enzyme pattern is normal in the presence of known disease, a "false negative" which may mean a complete walling off of the disease or no response by the host. In our series of orthopaedic cases, we have had no "false positives"—elevated levels of chymotrypsin inhibitor with no disease activity.

## CONCLUSIONS

Serial determinations of proteolytic-enzyme-inhibitor patterns have been most

valuable as a therapeutic guide in cases of osteomyelitis of the spine (especially tuberculous osteomyelitis) and in cases of tuberculous bone and joint disease in general. They have frequently been helpful in the differentiation of benign from malignant primary bone tumors, and they have often been used in the follow-up of patients with tumors as a means of confirming the presence of metastases. As a means of estimating the patient's "resistance" to the catabolism present, these methods offer additional information for the surgeon to use in reaching a presurgical judgment.

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## DISCUSSION

### Correction of Calcaneocavus

*(Continued from page 1253)*

can be adequately corrected by a triple arthrodesis done in a single-stage procedure. We would agree with the authors' principles of correction. The two-stage procedure would seem to be reserved for patients with deformities as severe as the ones described in this paper. If the two-stage operation will restore as good alignment in calcaneus feet as the authors have shown, I am an advocate of this operation.

I would like to point out that any procedure for the correction of calcaneus deformity should restore a useful range of plantar flexion in the ankle joint. Limited plantar flexion will greatly impair the functional result to be obtained by tendon transplantation.

Dr. Scheer (closing): In answer to Dr. Grice's question as to whether we use the two-stage stabilization procedure in all calcaneocavus feet, the answer is no! We have done a far larger number of single-stage stabilizations for this deformity than two-stage procedures. The two-stage operation was originally used only for the most severe deformities. However, we like the technical ease and the end results of the procedure and, therefore, also use it in less severe cases in which the second stage does not call for an unnecessary second anaesthetic. Such a situation obtains when both anterior and posterior tendon transfers are required. The posterior transfers are done at the time of the first stage and the anterior transfers at the second stage.

I want to congratulate Dr. Irwin on his excellent results. I would disagree with him in one respect, however. The first slide that we showed demonstrates that if a posterior wedge of bone is not removed from the subtalar joint and if the tuber angle remains unaltered, rotating the posterior tuber of the calcaneus to a horizontal position produces a severe or maximum equinus position of the talus in the ankle mortise. This I feel is undesirable from two standpoints: (1) the ankle joint is least stable when the talus is in an equinus position, and (2) as Dr. Grice pointed out in his discussion, if one expects the posterior tendon transfers to function, a satisfactory range of plantar flexion of the ankle joint must be preserved.

# Popliteal Cyst

## A Clinicopathological Survey *

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In reviewing the literature, one is impressed by the number of names that have been used to describe cystic lesions of the popliteal space. They have been called popliteal cysts, Baker's cysts, posterior herniae of the knee joint, synovial cysts, semimembranosus bursae, and gastrocnemio-semimembranosus bursae. In an attempt to clarify the concept of these lesions we have evaluated all the cystic enlargements of the popliteal space excised at the Mayo Clinic during a given period. The results are here reported.

### HISTORICAL BACKGROUND

Cystic tumors about the knee in association with rheumatoid arthritis were first mentioned by Adams, who called the condition "dropsy" of the knee. Subsequently there was some difference of opinion among early writers as to the origin of the lesions. Some [3, 4, 20, 33] thought that they were true herniations of the posterior part of the knee joint, while others [14, 15, 19, 42] thought that they arose primarily from popliteal bursae. According to Billroth, Gruber was the first to differentiate the lesions as to origin. Most authors have found some tendency of the cyst to be associated with other abnormalities of the knee joint, including osteo-arthritis [3, 33, 35, 42], rheumatoid arthritis [1, 3, 33], torn cartilage in the knee [9, 36], trauma to the knee [14, 41], brucellosis [23], and pigmented villonodular synovitis [6]. Numerous other reports of the condition have been recorded [5, 12, 13, 21, 26, 31, 37, 39].

The anatomy of the synovial membrane of the knee joint was adequately described by Fullerton in 1916. He noted the many bursae in the neighborhood of the knee, but stated that the suprapatellar bursa and the bursa between the medial head of the gastrocnemius and the medial tibial condyle are the ones that most often communicate with the knee joint. He also noted that the gastrocnemius bursa often communicated with the bursa between the semimembranosus and the medial head of the gastrocnemius. He said that these bursae frequently share in an infection of the knee joint as a result of "pumping" of infection from the joint into the bursae by motion. He mentioned also that in flexion of the knee the contents of the bursae might be emptied into the joint but that in extension this did not occur since the extended position caused the valve-like communication to be closed by tension.

More recently, Wilson, Eyre-Brook, and Francis made a detailed study of the anatomy of the bursae of the medioposterior region of the knee. Their classification has been used as the basis for our study. They described six primary bursae of this region, and stated that the semimembranosus and gastrocnemius bursae are most frequently involved in the formation of popliteal cysts.

It is usually the bursa beneath the popliteus that is concerned in the formation of a popliteal cyst on the lateral side of the popliteal space. Fullerton found that this bursa

* Abridgment of thesis submitted by Dr. Burleson to the Faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of Master of Science in Orthopaedic Surgery.

† The Mayo Foundation, Rochester, Minnesota, is a part of the Graduate School of the University of Minnesota.

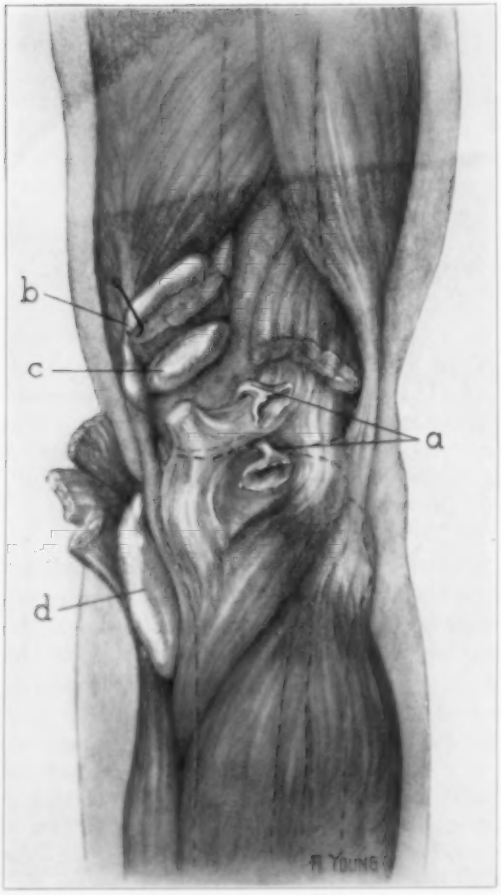


FIG. 1

Common origins of popliteal cyst. *a*, Herniation of posterior capsule, above and below the oblique popliteal ligament; *b*, semimembranosus bursa, lying between the semimembranosus and the medial head of the gastrocnemius; *c*, the gastrocnemius bursa, lying beneath the medial head of the gastrocnemius; and *d*, anserine bursa, lying beneath the tendinous insertion of the pes anserinus.

is inconstant and that it rarely communicates with the knee joint.

Haggart stated that a hernia of the posterior part of the knee joint is usually situated below the oblique popliteal ligament and slightly toward the medial side. Gruber had thought that it might occur either below or above this ligament. The most common sites of origin of popliteal cysts are depicted in Figure 1.

Concepts regarding the microanatomy of synovial membrane and popliteal cyst have changed with increasing knowledge. According to King[29], Winslow, in 1743, thought that the synovial membrane was epithelium. Later it was thought to be endothelium and mesothelium. The true connective-tissue origin of the synovial membrane was demonstrated by Key, in 1925, after hemisynovectomy on the basis of differentiation or maturation of the fibroblasts in regeneration of the synovial membrane. This concept has been upheld by others[10, 29, 38].

Hammar, in 1894, interpreted bursal linings as real connective tissue, and Key, in 1932, expressed the belief that these bursae are lined by a connective tissue practically identical with the synovial membrane. Others[18, 30, 32, 40] have concurred in this view and have pointed out the pleomorphic character of these cells in the bursae.

The functional origin of bursae has been pointed out by several writers[2, 8, 17], together with the ability of the surrounding tissues to form a synovium-like membrane at the point of stimulus at some distance from a joint.

## MATERIAL AND METHOD

This report is concerned chiefly with eighty-two patients who underwent surgical treatment for popliteal cyst. One patient had the lesion bilaterally, so that a total of eighty-three surgical procedures were performed. These patients were treated during the ten-year period from January 1, 1944, through December 31, 1953. During this time an additional 116 patients with a clinical diagnosis of popliteal cyst were seen who did not have surgical treatment. Cases of anserine, prepatellar, or other bursal enlargement about the lateral aspect of the knee were excluded and only those enlargements occurring in the popliteal space were considered.

Roentgenograms, available on all but eleven patients, were evaluated as to the

presence of the tumor and associated conditions in the knee joint.

The excised specimens were available for gross and microscopic examination in all but two cases. Several sections were cut through various parts of each cyst for histological study so that the usual and unusual features of each specimen were demonstrated.

To determine the end results and the incidence of recurrence, follow-up observations were made on the basis of either a return visit by the patient or a questionnaire returned by him. In this way follow-up data were obtained on 86.6 per cent of the patients.

FIG. 2

Popliteal cyst in a child aged five years. The lesion is at the level of the joint with no associated disease of the joint.

## CLINICAL SURVEY

Of the eighty-three operations for popliteal cyst, forty-nine were performed on the left side and thirty-four on the right. Of the eighty-two patients, fifty-seven were males and twenty-five were females. The average age was thirty-nine years, the oldest patient being seventy-seven and the youngest four. Eighteen of the patients treated surgically were children fifteen years of age and less (Fig. 2).

The known duration of the lesion in these patients ranged from five days to eighteen years. In ten of the patients there was a history of trauma, but this history was not suggestive of a uniform type of trauma. Four patients had undergone a previous attempt at surgical removal of the cyst, and one patient had undergone two such attempts.

### *Symptoms and Signs*

The presence of a mass was the chief concern of sixty-eight of the eighty-two patients treated surgically, but fourteen had not noted the mass prior to examination. The mass extended into the calf in four patients and to the left of the tendo achillis in one, and it appeared intermittently in one patient. Twenty-eight patients had no symptoms associated with the mass, while forty-six complained of local pain, often described as "aching". Other signs and symptoms were less apparent. Locking was present in only two patients; at operation this proved to be associated with tears of the posterior cartilage. Stiffness was a complaint in thirteen instances, and a limp in two. Nine patients had associated swelling within the joint; seven of these demonstrated other associated abnormalities of the joint, and two gave a history of intermittent swelling of the joint suggestive of drainage from the popliteal cyst into the joint, or vice versa.

### *Associated Abnormalities*

Of the 198 patients treated surgically and non-surgically, eighty-nine showed evidence, clinically or roentgenographically (Figs. 3 and 4), of associated abnormalities of the knee joint. Osteo-arthritis led the list, being present in forty patients, and rheumatoid arthritis was present in twenty-seven (Table I). This high incidence of associated disease of the knee joint indicates that such conditions must be a factor in the occurrence of popliteal cyst.

Of the thirty-four patients treated surgically with associated conditions, the majority had lesions that were bursal in origin (twenty patients), that communicated with the

TABLE I

CONDITIONS ASSOCIATED WITH POPLITEAL CYSTS IN EIGHTY-TWO PATIENTS TREATED SURGICALLY AND 116 TREATED NON-SURGICALLY

| Associated Condition | Patients | | |
|---|---|---|---|
| | Surgical | Non-Surgical | Total |
| Osteo-arthritis | 13 | 27 | 40 |
| Rheumatoid arthritis | 13 | 14 | 27 |
| Injury of cartilage | 2 | 2 | 4 |
| Osteochondromatosis (loose bodies) | 4 | 3 | 7 |
| Fibrositis | 1 | 3 | 4 |
| Non-specific synovitis | 1 | 0 | 1 |
| Gout | 0 | 2 | 2 |
| Tuberculosis | 0 | 1 | 1 |
| Giant-cell tumor | 0 | 1 | 1 |
| Pellegrini-Stieda disease | 0 | 1 | 1 |
| Bipartite patella | 0 | 1 | 1 |
| Total | 34 | 55 | 89 |

knee joint (twenty-six patients), and that possessed a synovium-like lining (nineteen patients). In five patients the site of origin of the cyst and its communication with the joint were undetermined.

*Roentgenographic Observations*

Preoperative roentgenograms were made in seventy-one of the eighty-two patients treated surgically. In addition to showing some of the associated conditions of the knee joint, the roentgenograms were considered diagnostic of Baker's cyst in forty-four patients and suggestive of a soft-tissue tumor in the popliteal space in fourteen patients; they were interpreted as negative in only thirteen patients. In forty-four patients the lateral roentgenograms definitely showed shadows which were classified as being above,



FIG. 3



FIG. 4

Fig. 3: Inflammatory rheumatoid arthritis coexistent with popliteal cyst.

Fig. 4: Popliteal cyst situated mostly below the joint line and associated with mechanical difficulties in the knee joint due to osteo-arthritis and loose bodies.

below, or at the level of the joint line (Figs. 2 and 4) and which then were correlated with the origin of the cyst as found at operation. However, we were not able to determine, on the basis of the position of a cyst as revealed by roentgenograms, whether it was bursal or hernial in origin. Neither was it possible, by routine roentgenographic observation, to determine whether a cyst communicated with the joint space. Pneumoroentgenography might aid in such a determination[13, 31, 36], but this procedure was not employed in our series, nor was it felt to be of sufficient clinical value to justify its use.

*Surgical Anatomy*

At operation, forty-six of the excised cysts were found to be bursal in origin. The close proximity and frequent unity of the gastrocnemius bursa and the semimembranosus bursa led us to designate them by the term *gastrocnemio-semimembranosus bursa*, which was used by Wilson and his associates. These cystic masses were all quite firmly attached to one or both of the involved muscles. Twenty-six of the cysts were interpreted as hernial, that is, as protruding abnormally through the posterior capsule of the knee. Most of them were medial in location, some were in the mid-line, and only one was situated laterally. In eleven instances, the cyst could not be accurately classified as bursal or hernial in origin.

Communication of the cyst with the joint was apparent in fifty-four of the eighty-three cysts treated surgically. These included twenty-seven herniae, twenty-two bursae, and five unclassified tumors. Twenty of the cysts definitely did not communicate with the joint, and hence all of these were considered bursal in origin. In nine, it was not possible to determine whether or not the cyst communicated with the joint. The surgical procedure in each case was total excision of the cystic wall and its connection, if any, with the joint. The opening into the joint was closed in twenty-eight cases. The opening was not closed in most because of the impossibility of closure; it seemed to have been left open purposely in only six cases. Iodine or other caustics were used in only four instances in an attempted closure of a defect in the capsule; these agents are believed to be of doubtful value.

## HISTOPATHOLOGICAL CHARACTERISTICS

Specimens were available from eighty-one of the eighty-three surgical procedures. On the basis of gross appearance the specimens were divided into three categories. In the first category were the fibrous cysts, which sometimes were lobulated and which had a discrete limiting wall, usually one to two millimeters thick, and a smooth-to-glistening inner surface. There sometimes were chorda-like connections on the inner surface. In the second category were the cysts in which the synovial bursa had a less well defined wall that seemed to blend more into the surrounding connective tissue. The wall was usually thicker than in cysts of the first category, varying from two to five millimeters. The inner surface was less shiny, but at times was smooth or demonstrated villus formation. These cysts were sometimes lobulated and sometimes showed chordae. In the third category were the inflammatory cysts, which had a very thick wall (up to eight millimeters) and an inner surface that might appear shaggy from adherent fibrinous exudate. At operation the wall of this type might be oedematous and injected. Areas of hemosiderin pigmentation or cartilage formation were occasionally seen in cysts of the last two types.

On a microscopic basis it was possible to classify most of the cysts into the categories described, although a few fell into a fourth category, which has been termed *transitional*. The cysts have arbitrarily been divided in the manner indicated, although the evidence to be presented indicates that they may all be variations of the same type of lesion.

The fibrous cyst has a wall that is one to two millimeters thick and is characterized microscopically by the presence of fibrous tissue that is largely hyalinized (Fig. 5-A). The innermost surface of this wall is usually lined by a single layer of thin, flattened

cells often called by earlier writers endothelium. Some areas may be devoid of these surface cells, and in other areas there may be spherical hyalinized rice bodies near the surface lining. There is usually very little inflammatory reaction in the wall.

The cyst lined with synovial membrane (Fig. 5-B) has less dense fibrous connective tissue in its wall. Toward the inner surface there is a change of cell form, with typical cuboidal or columnar synovial cells lining the surface. In the walls of the cyst, masses of hyalin, cartilage, and even bone are sometimes found. There may be villus formation, which is especially prominent in cysts associated with rheumatoid arthritis. There is a varying degree of inflammatory reaction characterized by the presence of histiocytes, lymphocytes, and plasma cells.

FIG. 5-A

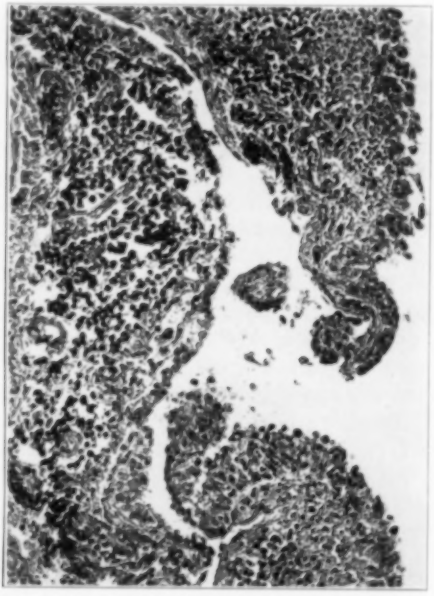

FIG. 5-B

Figs. 5-A to 5-D: Examples of the four categories of popliteal cysts.

Fig. 5-A: Fibrous cyst. Fibroblastic lining, much collagen, and rice body on the right (hematoxylin and eosin, × 300).

Fig. 5-B: Synovial cyst. Note thickened lining of synovium-like cells, villus formation, and round-cell infiltration (hematoxylin and eosin, × 140).

The cyst with an inflammatory lining (Fig. 5-C) has a fibrous wall with varying degrees of infiltration by lymphocytes, plasma cells, histiocytes, and even polymorphonuclear cells. There is no definite lining, but the inflammatory cells are intermingled with fibroblasts of the wall. Proliferating capillaries are numerous. There are varying degrees of fragmentation along the inner surface which is frequently covered by a fibrinous exudate. Small islands of cartilage are occasionally found in the wall.

In the fourth category (Fig. 5-D), the cyst represents a transition between the fibrous cyst and the synovial cyst. In small foci the flattened lining cells assume some of the features of synovial membrane. These transitional forms suggest that all the cysts are similar and that in the fibrous cyst the synovial cells are flattened. On the other hand, perhaps mature-appearing synovial membrane differentiates from fibroblasts and thus produces these transitional forms.

In Table II is shown how the eighty-one cysts for which surgical specimens were

available were distributed as regards the type of lining observed microscopically and as regards gross anatomical origin. It is obvious that one cannot determine the origin on the basis of microscopic appearance. Some bursae had typical synovial lining, while some herniae had typical fibrous lining.

It should be added that in addition to inflammatory cells in the lining or wall of the cysts, giant cells were occasionally encountered. These were apparently the result of hemorrhage rather than of infection, as they were usually associated with hemosiderin. Foam cells, which upon staining were shown to contain fat, were seen occasionally, usually near the surface lining. Polymorphonuclear neutrophils were seen in only one cyst — a cyst in which there was an inflammatory lining.

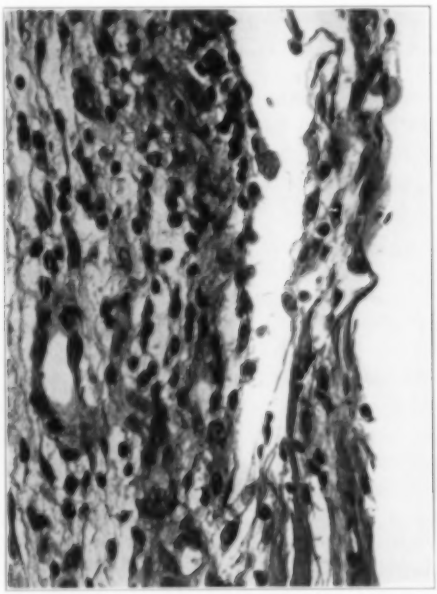

FIG. 5-C

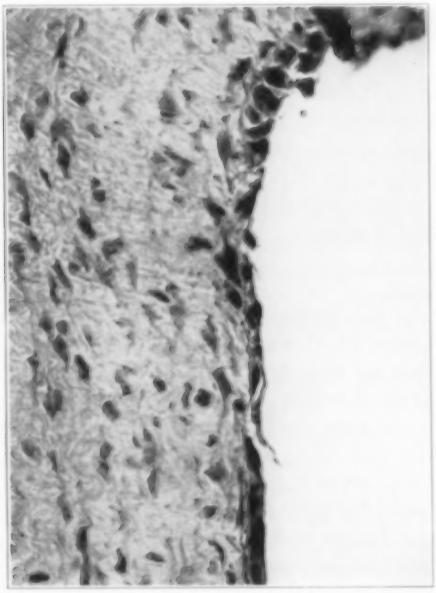

FIG. 5-D

Fig. 5-C: Inflammatory cyst. Note fibrin on surface below, and fibroblasts infiltrated with histiocytes, plasma cells, lymphocytes, and, in this one instance, polymorphonuclear cells (hematoxylin and eosin, × 400).

Fig. 5-D: Transitional cyst. Note typically fibrous lining below and the change to cuboidal cells near the top (hematoxylin and eosin, × 400).

## FOLLOW-UP SURVEY

Follow-up data were available on seventy-one patients (seventy-two cysts and surgical procedures). Of the eleven patients on whom data were not obtained, four had been operated on so recently that it was not feasible to include them here.

There were five recurrences, all within the first two or three months after operation; no patient was known to have had a second operation. Two of the recurrent cysts were symptomless. Only one was associated with other disease of the joint (rheumatoid arthritis); this was the only recurrence of a cyst that was said to communicate with the knee joint. In this, the capsular defect had not been closed at operation. Two cysts were said not to have communicated and the other two were indeterminate as to such a communication. Since there was only one recurrence in the twenty-eight patients in whom the capsule was left open, it would be improper to infer that leaving the capsule open in the presence of a communication is a major cause of recurrence. Associated lesions of the joint likewise were not a major reason for recurrence in this small group.

TABLE II

RELATIONSHIP BETWEEN TYPE OF LINING OBSERVED MICROSCOPICALLY AND GROSS ANATOMICAL ORIGIN AS DETERMINED IN EIGHTY-ONE CASES IN WHICH SURGICAL SPECIMENS WERE AVAILABLE

| Type of Lining | No. of Cases | Origin | | |
|---|---|---|---|---|
| | | Hernial | Bursal | Undetermined |
| Synovial | 26 | 8 | 15 | 3 |
| Fibrous | 48 | 18 | 25 | 5 |
| Inflammatory | 3 | 0 | 3 | 0 |
| Transitional | 4 | 1 | 2 | 1 |
| Total | 81 | 27 | 45 | 9 |

The matter of persistence of other signs and symptoms after operation also was evaluated in the follow-up. Of twenty-seven patients who had complaints, twenty-one had associated disease of the joints which, it seems obvious, was responsible for the complaints of pain, swelling of the joint, and symptoms involving other joints. In two patients who did not have recurrence a similar cystic tumor later developed on the opposite side.

## COMMENT

The problem of the differential diagnosis of popliteal cyst from aneurysm was suggested by Gruber, in 1885, who assumed that an enlarged non-communicating bursa that lay superficial to the popliteal artery would transmit its pulsation. This seems unlikely. However, Janes has told us of a recent patient in whom the popliteal artery crossed an enlarged cyst superficially and longitudinally and was firmly adherent in the wall of the cyst. The pulsation and bruit of the artery were associated with the mass, and the diagnosis of popliteal aneurysm was ventured. Arteriography demonstrated the true relationship prior to surgical intervention.

In our series, popliteal lipoma was not confused with popliteal cyst, but Haggart reported one case of lipoma and one of hyperplastic fat pad that were thought preoperatively to be popliteal cysts. Roentgenograms should help to avoid this error, since a lipoma gives a radiolucent shadow. A further diagnostic problem might be popliteal varices, as pointed out by Moore, but this was not encountered in our series.

Several authors[9, 11, 20] have noted that patients with popliteal cysts may present symptoms suggestive of internal derangement of the knee. Two of our patients had associated tears of posterior cartilage. We did not find, as Haggart and Wheeler did, that a hyperextension type of trauma to the knee caused the development of popliteal cyst.

As has been mentioned, in no patient was tuberculosis, brucellosis, or pigmented villonodular synovitis associated with a popliteal cyst in our series of cases. Harris reported, however, that he had seen six patients in whom brucellosis was associated with a popliteal cyst, and Bickel recently treated two patients who had monarticular disease and a large popliteal cyst, in each of whom the joint and the cyst were the site of pigmented villonodular synovitis. Ivins observed a popliteal cyst associated with tuberculous infection of the knee joint. Along with the high incidence of osteo-arthritis, rheumatoid arthritis, and osteochondromatosis, these findings seem to indicate that associated disease of the knee joint may be a causative factor in the formation of popliteal cyst.

Several authors, including Haggart, and Kuhn and Hemphill, have reported that routine roentgenographic examination of the knee in the presence of a popliteal cyst gives negative results. However, we believe that lateral roentgenograms are diagnostic in more than 60 per cent and suggestive of the condition in an additional 19 per cent.

Tight closure of the capsule has been advocated by a number of authors as prophylaxis against recurrence after operation [14, 21, 31, 33, 37]. The results in our series suggest that tight closure is not necessary, although it is desirable if possible. We have not noted postoperative effusion in the knee joint, said by Haggart and Wheeler to be frequent, in cysts in which there was communication with the joint.

In the microscopic classification of the walls of the cysts we have purposely refrained from using a name that definitely indicates the origin of the lining cells. We have used instead, as already indicated, the descriptive terms *fibrous, synovial, inflammatory,* and *transitional* to indicate the histological characteristics. As has also been indicated, it was not of practical value to classify the popliteal cysts on a microscopic basis since it did not help in determining their origin or the likelihood of recurrence. The miscroscopic examination may, however, give important information, such as that which would lead to a diagnosis of pigmented villonodular synovitis or tuberculosis, or it may suggest other specific infections such as brucellosis.

## SUMMARY AND CONCLUSIONS

Of 198 patients with popliteal cyst who were seen during a ten-year period, eighty-two underwent eighty-three operations—total excision of the cyst. The patient had usually complained of a mass and of aching pain in the region of the knee. More than a fifth of the eighty-two patients were less than sixteen years old. Although other disease of the knee joint, which was associated with the cyst in 45 per cent of the 198 patients, apparently did not predispose to recurrence of the cyst after operation, it did seem to increase the chance that the patient would continue to complain of trouble with the joint after operation.

At operation, forty-six of the eighty-three cysts seemed to arise from bursae, twenty-six from herniae, and eleven from indeterminate sites. Communication of the cyst with the joint was evident in fifty-four, twenty-seven of these being hernial in origin, twenty-two being bursal, and five being indeterminate. Failure to close the capsule when the cyst communicated with the knee did not seem to predispose to recurrence.

Pathologically the cysts were classified as fibrous, synovial, inflammatory, and, in a few instances, transitional. No particular type or lining characterized either the bursal or the hernial cyst.

Only five patients had recurrence of the cyst, but twenty-seven had persistence of some degree of symptoms, twenty-one of whom had associated disease of the knee joint.

The name *popliteal cyst* seems preferable to the names used heretofore, regardless of where the cyst arises, since all these lesions apparently behave alike clinically and pathologically, have the same indications for treatment, and terminate similarly.

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# Lipoma of the Tendon Sheath

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Lipoma is rarely encountered in tendon sheaths. Two patients, recently operated on for this condition at the Mayo Clinic, prompted a review of the literature.

Two forms of lipoma of the tendon sheath have been reported, lipoma arborescens and lipoma simplex symmetricum. The former term was first used by J. Mueller, in 1838, to describe a fatty tumor of the knee which presented branched villus-like projections. Virchow, in 1847, used the term in describing a similar tumor which he found located in the abdominal cavity of a patient [20]. In his textbook of tumor pathology, published in 1893, Bland-Sutton presented a drawing of an arborescent lipoma of the shoulder. Billroth, in 1885, was the first to mention this type of tumor in association with tendon sheaths.

The name *lipoma simplex symmetricum* is applied to lipoma of the tendon sheath which does not present the branched villous projections of the arborescent type. Each type of lipoma occurs bilaterally. The literature from 1922 to the present was searched for cases of lipoma similar to the two seen at the Mayo Clinic, and as far as it has been possible to determine, only forty-three cases have been reported. Strauss' study in 1922 is considered authentic and we have included his cases in our review.

## ETIOLOGY

As in most cases of neoplasm, the exact origins of lipoma arborescens and lipoma simplex symmetricum are unknown. According to Strauss, early writings on the subject suggested its probable relationship to tuberculosis; other authors declared that chronic inflammation in any form might produce such abnormal growth. Lambret, Heuter, and Tichoff suggested in 1895 that rheumatoid arthritis might be the initiating factor. Subsequent authors, however, have agreed unanimously that the lesions arise as true neoplasms.

## CLINICAL MANIFESTATIONS

Of the forty-three reported cases of lipoma of the tendon sheath, eighteen occurred in males and nineteen in females. No data concerning the sex of the other six patients were found. The oldest patient in whom the tumor occurred was seventy years of age and the youngest patient was six years old. The majority of patients were less than forty years of age (Table I).

The symptoms were primarily those associated with any tumor of the soft tissues, and the majority of patients complained of mild aching pain in the affected part. Occasionally an acute inflammatory condition was present with swelling, redness, and warmth of the overlying tissues. Frequently, crepitus of the soft tissues was observed. Symptoms were often aggravated by overuse of the affected extremity. In 1933, Grandclaude, Razemon, and Bizard reported rupture of the tendon of the extensor carpi radialis which had been involved by an arborescent lipoma.

In thirty of the cases reported in the literature, the lipomata occurred in the hands and wrists only and in nine in the feet and ankles only. Two patients were reported as

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TABLE I

FORTY-FIVE CASES OF LIPOMA OF THE TENDON SHEATH *

| Author and Date of Report | Sex and Age (*Years*) | Form of Lipoma | Site |
|---|---|---|---|
| Pavloff (Bogoluboff); 1885 † | F 30 | Arborescens | Flexor tendons of thumb |
| Haumann; 1887 † | M 27 | Arborescens | Hands, bilateral; extensor digitorum communis |
| Sprengel; 1888 † | F 10 | Simplex | Ankles, bilateral; peroneal and extensor communis longus |
| Haeckel; 1888 † | M 21 | Arborescens | Hand, left; extensor digitorum communis, third and fourth flexors, and extensor pollicis longus and carpi radialis longus |
| Kurz; 1888 † | F 28 | Arborescens | Wrist, right; extensor digitorum communis of index, long, and ring fingers |
| Jaksch; 1888 † | M 23 | Simplex | Feet, bilateral; extensor hallucis longus |
| Sendler; 1891 † | F 14 | Arborescens | Hand; extensor digitorum communis of index, long, and ring fingers |
| Kummer; 1894 † | M 27 | Arborescens | Wrists, bilateral; extensor digitorum communis, proprius indicis, and digiti quinti |
| Deces (Fossier); 1895 † | F 21 | Simplex | Wrists, bilateral; extensor radialis brevis |
| Tichoff; 1895 † | M 34 | Arborescens | Hands, bilateral; flexor tendons |
| Meyer; 1897 † | F 48 | Arborescens | Hands, bilateral; extensor digitorum communis |
| Pancritius; 1897 † (2 cases) | M 34 | Simplex | Hands, bilateral; extensor digitorum communis; ankle, left; peronaeus |
| | F 20 | Simplex | Ankle; peronaeus longus and brevis |
| Cassanello; 1900 † | F 30 | Arborescens | Hands, bilateral; extensor digitorum communis, proprius indicis, and digiti quinti |
| Lambret; 1902 † | 8 | Arborescens | Wrist, right; extensor digitorum communis |
| Bülmann; 1904 † | M 26 | Simplex | Wrists; bilateral; abductor pollicis longus and extensor pollicis brevis |
| Michailoff (Bogoluboff); 1910 † | M 32 | Arborescens | Wrists, bilateral; extensor carpi radialis longus |
| Bogoluboff; 1910 † | F 21 | Arborescens | Wrists, bilateral; extensor digitorum communis and flexor digitorum on right |
| Strauss; 1922 | F 27 | Simplex | Hands, bilateral; extensor digitorum communis and flexors of fingers on right |
| Martin and Grenier; 1922 | F 62 | Simplex | Hand; extensor of finger |
| White; 1924 (2 cases) | M 38 | Arborescens | Ankle; peronaeus and "medial" |
| | M 35 | Arborescens | Ankle; posterior tibial |
| Filho; 1925 | F 24 | Arborescens | Wrist; flexor tendons |
| Auvray; 1926 | | Simplex? | Hand; flexors of thumb, index, and ring fingers |
| Mouchet; 1926 | | Simplex? | Hand; flexors in palm |
| Desbonnets; 1926 | M 45 | Simplex | Hand, right; flexors |
| Schulte; 1927 | M 67 | Simplex? | Wrist, left; flexor digitorum profundus |
| Muller; 1928 | F 62 | Arborescens | Hand; flexor of finger |
| Klotz; 1928 | M 70 | Simplex | Hand; flexors of fingers |
| Mannini; 1928 (3 cases) | F 67 | Arborescens | Hand; flexor of index finger |
| | F 45 | Simplex‡ | Ankle, right; Achilles tendon |
| | F 16 | Arborescens | Ankle, right; Achilles tendon |
| Chiarissimo; 1929 | F 28 | Arborescens | Foot, right; peronaeus tertius |
| Valdoni; 1931 | M 19 | Arborescens | Hands, bilateral; extensor digitorum communis and flexors of fingers on right<br>Ankles, bilateral; peroneals |
| Straus; 1931 | M 34 | Arborescens | Hand; flexor to right ring finger |

TABLE II *(continued)*

| Author and Date of Report | Sex and Age *(Years)* | Form of Lipoma | Site |
|---|---|---|---|
| Grandclaude, Razemon, and Bizard; 1933 | M 31 | Arborescens | Hand; external pollicis longus and extensor carpi radialis with rupture |
| Canavero; 1934 | 56 | Arborescens | Hand; flexor of left index finger |
| Geschickter and Lewis; 1934 | | | 2 cases; no data |
| Pariset; 1938 | M 13 | Arborescens | Ankle; tibialis posterior and anterior and flexor hallucis longus |
| Jadevaia; 1940 | F 6 | Simplex | Hand, left; flexor digitorum sublimis of index finger |
| Charache; 1942 (2 cases) | F 40 | Simplex | Hand; extensor digitorum communis |
| | M 15 | Arborescens | Hand; extensor pollicis longus; extensor digitorum communis |
| Sullivan, Dahlin, and Bryan (Case 1) | M 33 | Arborescens | Hand, right; extensor digitorum communis |
| Sullivan, Dahlin, and Bryan (Case 2) | F 39 | Simplex | Ankles, bilateral; tibialis anterior |

* Forty-three cases from literature; two of our own.
† Data reported by Strauss.

having tumors of both the upper and lower extremities; one of these patients had arborescent lipomata on both hands and both ankles. In fourteen cases the neoplasm was present bilaterally. In two cases there was no information concerning the site of the lesion. Often several tendons in one limb were involved. Extensor tendons appeared to be affected more frequently than flexor tendons.

In the cases reported, symptoms continued for varying periods of time—from several weeks to twenty years.

## PATHOLOGICAL CHANGES

At the operating table, the tumor is seen to be a soft mass palpable under the skin along a tendon sheath. Distention of the sheath due to effusion may be observed. Surgical exposure of the exterior surface of the sheath may reveal a smooth, glistening mass which looks much like the lipomata found ordinarily in other parts of the body; however, the color is more often orange than the usual yellow. On opening the sheath, typical villous and nodular projections may be seen (Fig. 1-A). These vary in length from one to three or four millimeters and have a glistening orange or yellow surface. Occasionally, degenerated and hyalinized villi lie as loose bodies within the sheath. Both the arborescent and simplex symmetricus forms of the tumor are composed of finely lobulated and vesicular fatty tissue which grows from the sheath, and grossly is indistinguishable from it. The distinguishing feature of the arborescent type of lipoma seems to be the presence of villi.

Microscopically, the tissue is composed chiefly of adipose connective-tissue cells (Fig. 1-B). A histological section cut at right angles to the synovial membrane shows clearly the tree-like branching villous nature of the arborescent variety. Fibrous connective tissue may be seen at the bases of the villi. A sprinkling of lymphocytes and plasma cells is often observed. Many authors have mentioned the prominent vascularity of the lipomatous tissue which sometimes contains hemorrhagic areas. The chronic inflammatory cells, vascularity, and zones of hemorrhage in the tumor may result from trauma to the villous projections.

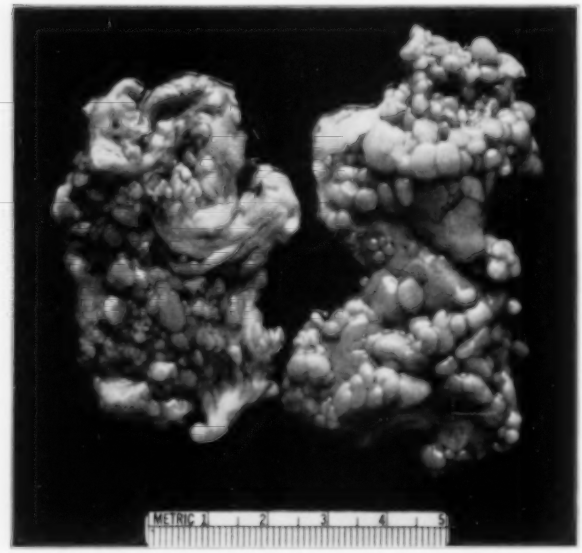


FIG. 1-A

Case 1. Inner surface of tendon sheaths showing pedunculated polyp-like lipomatous masses in arborescent lipomata.

## TREATMENT

Several of the earlier authors reported treatment consisting in incision and drainage. In cases of incomplete excision of the tumor, continued viability or recurrence was observed. Complete surgical excision of the involved sheath is essential for successful treatment.

## REPORT OF CASES

CASE 1. A contractor, thirty-three years old, registered at the Clinic on February 8, 1955, complaining of a mass on the dorsum of the right wrist which he had first noticed two and a half years previously. The tumor had slowly increased in size and had caused occasional aching pain in the wrist and hand. He could recall no history of injury to the wrist, and there was no redness, swelling, or other evidence of inflammation. He had found no other masses on his body. General examination included a roentgenogram of the chest and the routine blood counts and urinalysis; the findings were within normal limits. A flocculation test for syphilis was negative and the sedimentation rate was fourteen millimeters in one hour (Westergren method). The value per 100 cubic centimeters for blood lipids was 388 milligrams; for fatty acids, 245 milligrams; and for cholesterol, 143 milligrams. The range of motion in all joints of the right wrist and hand was normal. On the dorsum of the right wrist and overlying the extensor tendons to the fingers was a soft palpable mass which extended from the metacarpophalangeal joints to a point one

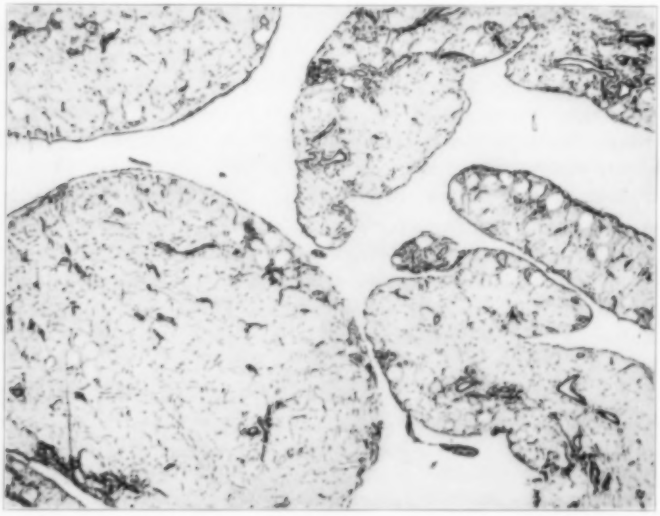

FIG. 1-B

The arborescent lipomata masses; a few small collections of lymphocytes and plasma cells may be seen (hematoxylin and eosin; × 31.5).

and one-half inches proximal to the dorsal carpal ligament. The mass corresponded in shape to the position of the tendon sheaths, and forcible extension of the fingers accentuated the appearance of the tumor. A roentgenogram of the wrist revealed only swelling of the soft tissues on the dorsum of the wrist and hand.

On February 21, 1955, the mass was removed through two incisions, one in the dorsum of the hand, and the other over the portion of the mass which lay proximal to the dorsal carpal ligament. A lipomatous mass indistinguishable from the tendon sheaths was removed. This mass was a typical arborescent lipoma (Figs. 1-A and 1-B). Since the operation the patient has had full function of his hand, and to date there has been no evidence of recurrence.

Case 2. A housewife, thirty-nine years old, registered at the Clinic on September 9, 1953, complaining of a painful mass on the anterior surface of the left ankle. The mass had been present for eighteen years. For two years prior to the examination she had had intermittent episodes of moderately severe pain over the tumor associated with redness and swelling of the soft tissues. On several occasions ecchymotic discoloration of the skin occurred. Symptoms were always more pronounced after walking and they were relieved by rest. During these two years she had also observed a mass on the anterior surface of the right ankle, with occasional dull pain in the area. Her physician had made a diagnosis of superficial thrombophlebitis.

Fig. 2

Case 2. Lipoma simplex symmetricum of anterior tibial tendon showing lipomatous masses surrounding the tendon.

A general examination at the Clinic revealed a rather obese woman with palpable tender masses along both the right and left anterior tibial tendons. Both tumors were approximately the same size, one by two by three centimeters; the mass on the left anterior tibial tendon was tender and more indurated than the one on the right.

During the examination a nodule was found in the patient's right breast. Biopsy of this lesion revealed adenocarcinoma, Grade 3, and radical mastectomy was performed. Pathological examination of the axillary nodes did not reveal metastasis. Treatment of the tumors at the patient's ankles was not undertaken at that time.

The patient returned to the Clinic on August 27, 1954. Examination revealed no evidence of recurrence of adenocarcinoma. Since her previous examination, she had suffered from only one episode of pain, swelling, and redness of the tumor on the anterior surface of the left ankle. On that occasion, the symptoms had subsided after rest in bed, elevation of the left lower extremity, and administration of sulfonamide drugs. She was again dismissed.

The patient was next examined on June 22, 1955, and again no evidence of adenocarcinoma could be found. However, since her last visit she had continued to have episodes of pain, swelling, and discoloration in the region of the left anterior tibial tendon. Examination of the patient's left lower extremity revealed a normal range of motion in the joints of the ankle and foot, but it was found that the mass overlying the anterior tibial tendon had increased in size. It now measured three by three by two centimeters. It was tender, and the skin over the tumor was red, and warmer than over the surrounding tissues. Forcible extension of the left foot increased her pain. The tumor on the right ankle was palpable but was not painful or inflamed. Surgical excision of the mass on the left ankle was advised, and on June 24, 1955, the tumor was exposed through a longitudinal incision over the anterior tibial tendon. A large amount of fat was found surrounding this tendon (Fig. 2). All lipomatous tissue including the tendon sheath was excised. Pathological examination of the tissue demonstrated areas of hemorrhage and inflammatory fat necrosis in the lipoma. After the operation the patient regained full use of her foot and ankle, and there has been no recurrence of the tumor.

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# Experiences with Poliomyelitic Scoliosis After Fusion and Correction *

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The behavior of paralytic scoliosis is not the same as that of the congenital and idiopathic types of scoliosis [2]. In the paralytic form the curve may continue to increase for many years after the onset of the paralysis, progressing even when the patient is in his teens. Because of severe involvement of the trunk muscles, instability of the spine may be a serious problem even if the scoliosis is at first relatively mild. Under these circumstances stability of the spine may be attained only following the development of a severe deformity. Such a deformity may lead to impairment of the vital functions; for example, the collapse of a badly paralyzed trunk may result in kinking of the ureters, which in turn may cause renal stasis. A severe cosmetic deformity may develop rapidly in a young patient in the presence of a relatively stable curvature of the thoracic spine. The degree of involvement of the trunk and extremities may vary considerably; hence it is difficult to predict whether adequate compensatory curves will develop.

In the treatment of this type of scoliosis, the goal is two-fold: to prevent progression of the deformity and to attain adequate functional stability of the trunk. Fusion of the spine is a method of treatment often used to secure this goal, and the purpose of the author's study is to determine the amount of correction obtained during the period of recumbent immobilization following fusion of the spine, to compare this with the correction maintained after the resumption of sitting and standing, and to investigate some of the factors which influence the final result.

## MATERIAL

From November 1940 to May 1952 eighty-six patients underwent spine fusion for scoliosis due to paralytic poliomyelitis at the Georgia Warm Springs Foundation. The data presented in this study were obtained from the clinical records and roentgenograms of these patients. There were fifty-two (60 per cent) females and thirty-four (40 per cent) males in this group. In eight of the patients the final end result could not be determined because the follow-up was inadequate. Accordingly there were a total of seventy-eight patients available for complete study. (Some data, such as initial correction and the occurrence of pseudarthrosis, are based on the whole series of eighty-six patients.)

In the majority of the cases, corrective wedging in plaster was not done before the operation. In most patients the fusion was done in several stages, the operations being one to three weeks apart. A total of 173 procedures were performed. Four to five intervertebral spaces were fused at each operation.

In seven cases the curves were relatively short, and the fusions, which covered the full length of the curves, extended over only five segments in four of the patients and over only six in three of them. Five of the patients required only a single operation. In the remaining patients seven to twelve segments were fused. Eight of these patients required three operations. In no patient did the fusion extend into the cervical region, the most cephalad vertebra included being the second thoracic. In only two patients was the fusion extended into the sacrum; this was done at a second procedure performed some

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Los Angeles, California, February 3, 1955.

TABLE I

| Age of Patient at Time of Fusion | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range: 10 to 30 years | | | | | | | | | | | Median: 15 years | |
| Age: | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21–30 |
| Number of patients: | 1 | 1 | 6 | 9 | 14 | 11 | 15 | 10 | 7 | 3 | 4 | 7 |

| Length of Time Between Onset and Operation | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range: 14 months to 23 years | | | | | | | | | | | Median: 5 years | |
| Number of years: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11–15 | 16–23 |
| Number of patients: | 2 | 7 | 11 | 9 | 15 | 10 | 2 | 5 | 1 | 4 | 15 | 4 |

years after the original operation. The median age of the patients at the time of operation was fifteen years and the median length of time since the onset of the disease was five years (Table I).

The surgical technique used in most of the operations was as follows: The spinous processes and laminae were exposed subperiosteally. The spinous processes at the distal and proximal ends of the exposed area were split to receive grafts while the remaining processes were removed. From the laminae, cortical strips were elevated laterally, soft-tissue attachments being left intact. Autogenous-tibial or iliac-strut grafts, one-quarter to three-eighths of an inch in thickness, were then placed on the denuded bleeding surfaces of the laminae and were wedged against the split spinous processes at the upper and lower ends of the exposed area. In six patients a Hibbs-type fusion was performed.

For the first ten days following the operation each patient wore a corset and remained recumbent on a firm mattress placed over a bed-board. In most cases a corrective jacket with hinges and a turnbuckle was applied as soon as possible after the operation. Correction of the curve was then obtained as rapidly as possible, usually within a few weeks, according to the method described by Irwin.

Exceptions to this procedure were thirteen patients with extensive or high thoracic curves. A Milwaukee frame was used for correction in these cases.

For the first three to four months after operation immobilization in the jacket or frame was maintained with the patient recumbent at all times. A cellulose acetate jacket, usually fitted with bilateral simple crutch attachments, was then made, and the patient was allowed to sit up and stand as soon as these activities could be tolerated.

For nine to twelve months the jacket was worn constantly whenever the patient was upright. Approximately one year after operation the jacket was replaced by a corset.

In the seventy-eight patients on whom complete data were obtained, the follow-up

TABLE II

CLASSIFICATION OF INITIAL CURVES IN EIGHTY-SIX PATIENTS

| Type of Curve | No. of Cases | Side | | Under 40 Degrees | From 40 to 60 Degrees | From 60 to 80 Degrees | Over 80 Degrees |
|---|---|---|---|---|---|---|---|
| | | Right | Left | | | | |
| Lumbar | 7 | 2 | 5 | 0 | 1 | 1 | 5 |
| Thoracolumbar | 48 | 29 | 19 | 12 | 7 | 19 | 10 |
| Thoracic and | 20 | 18 | 2 | 3 | 7 | 4 | 6 |
| lumbar | | 2 | 18 | 7 | 8 | 5 | 0 |
| Thoracic | 8 | 8 | 0 | 0 | 3 | 1 | 4 |
| Total C | 3 | 2 | 1 | 0 | 1 | 1 | 1 |

period ranged from fourteen months to eleven years, the average period being four years and one month.

## METHOD OF STUDY

It was felt that the most consistent results could be obtained by measuring the spinal curvatures as they appeared on anteroposterior roentgenograms of the spine made with the patient in a sitting position. The curvature shown on the roentgenogram made immediately before the operation, with the patient sitting without any apparatus, represented the maximum deformity (the base line), and the curvature shown on the roentgenogram made several months after the final operation (with the patient sitting and wearing a jacket) represented the maximum correction. Subsequently roentgenograms were made at regular intervals, with the patients both wearing apparatus and without support. Oblique roentgenograms made with the patient recumbent were also obtained in most instances and occasionally roentgenograms were made with the patient standing or bending to alternate sides. In order that these data could be readily compared with those obtained by Ponseti and Friedman, the same classification as to type and degree of severity of curve was used (Table II and Figs. 1-A through 1-E). It should be noted that fifty-seven (65 per cent) of the curves in the author's series were over 60 degrees.

FIG. 1-A
Lumbar curve.

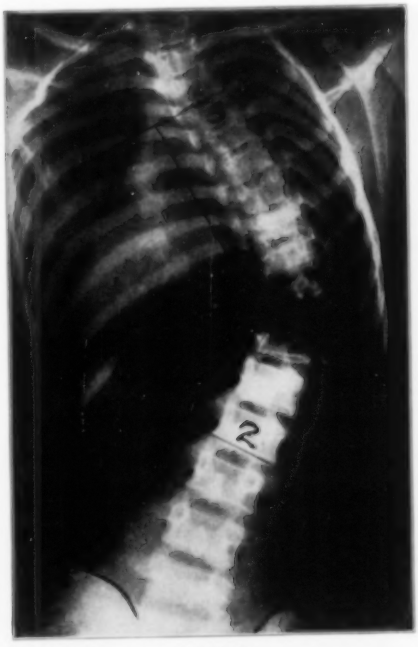

FIG. 1-B
Thoracolumbar curve.

## RESULTS

As was stated in the introduction, the purpose of the treatment is to prevent progression of the deformity and to attain adequate functional stability of the spine. In this study the final results were rated *worse*, *unchanged*, or *improved*. The curves which became decompensated and so severe that their final measurements placed them in a less favorable group than they were in before operation were considered *worse*; those with

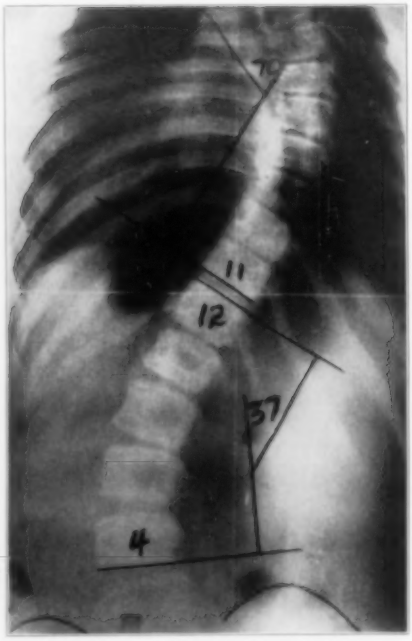


FIG. 1-C

Thoracic and lumbar curve.

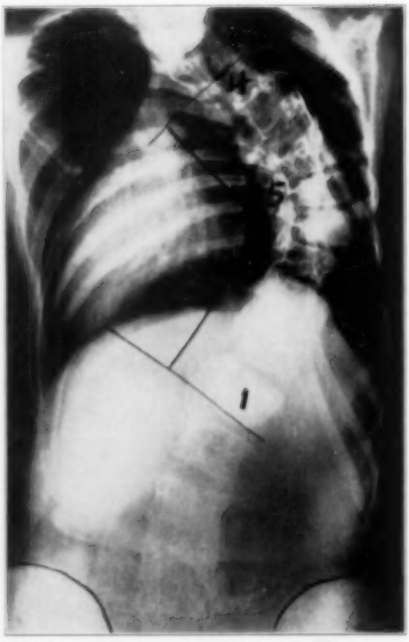


FIG. 1-D

Thoracic curve.

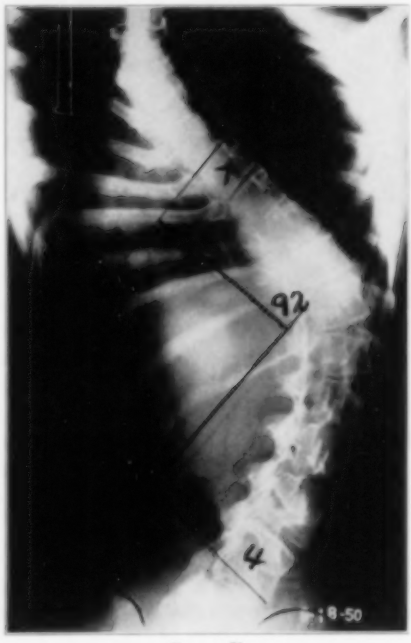


FIG. 1-E

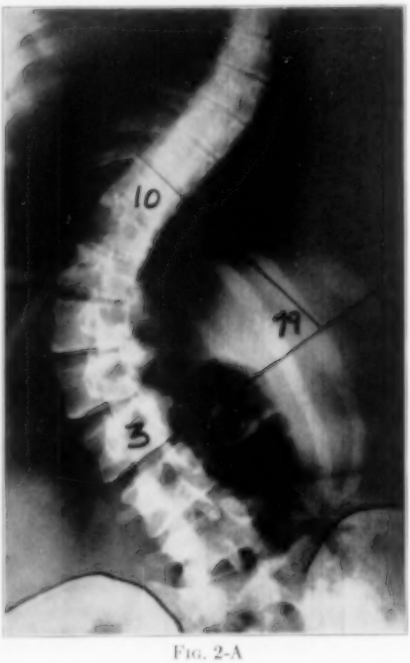


FIG. 2-A

Fig. 1-E: Total-C curve.

Fig. 2-A: Thoracolumbar curve in a girl sixteen years old. This preoperative roentgenogram was made with the patient sitting. The onset of paralysis had occurred six years previously.

final measurements that remained within the range of the groups to which the curves originally belonged were considered *unchanged* (Figs. 2-A, 2-B, and 2-C); and those with final measurements which placed them in a more favorable group were considered *improved* (Figs. 3-A and 3-B). In this way the absolute measurements as well as the degree of angular change could be employed in the analysis of the original as against the final correction.

Table III presents a comparison of the initial corrections and the final results; the figures in this table are grouped under the headings *worse*, *unchanged*, and *improved*. It is apparent that the majority of the patients (76 per cent) initially showed improve-

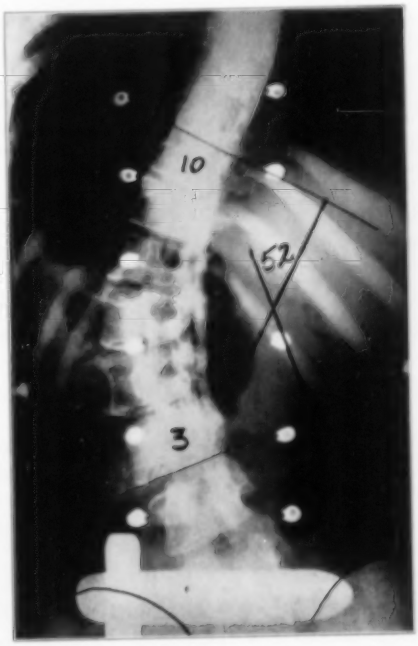


FIG. 2-B

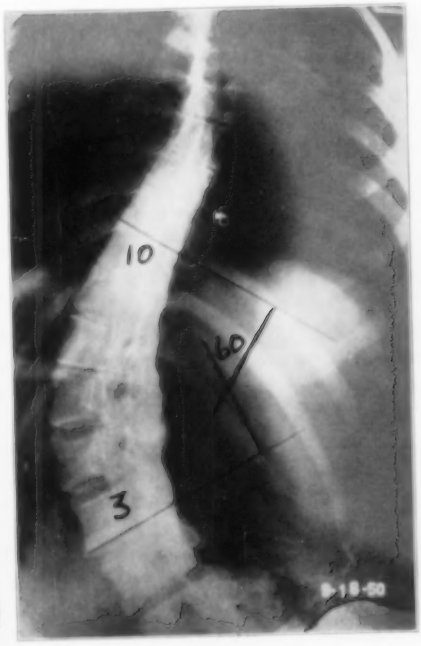


FIG. 2-C

Fig. 2-B: Four months after the operation there was an initial correction of 27 degrees. This roentgenogram was made with the patient in a sitting position, wearing a cellulose acetate jacket. The fused area extended from the seventh thoracic vertebra through the third lumbar vertebra.

Fig. 2-C: Final result more than three years after the operation. Although the patient was symptom-free and had lost only eight degrees of the initial correction, her curve belonged in the unchanged group, both the original and final measurements being between 60 and 80 degrees. A pseudarthrosis, previously visible at the level of the second lumbar vertebra, had closed spontaneously.

ment as a result of the operation and the postoperative treatment and that the remainder (24 per cent) were unchanged. By the end of the follow-up period, however, 9 per cent of the curves were worse than they had been before the operation, 47 per cent were essentially the same, and only 44 per cent still showed improvement. Table IV shows the breakdown of these curves according to type and final degree of severity. The best results were obtained in patients with the lumbar type of curve, 60 per cent of these being improved, while the worst results were obtained in patients with the thoracic and total-C types of curves, only 33 per cent of these being improved. It will be seen that forty of the seventy-eight patients (about 51 per cent) had final curves which were less than 60 degrees, whereas, originally, only 35 per cent of the patients had curves of less than 60 degrees.

TABLE III

COMPARISON OF INITIAL CORRECTION WITH FINAL RESULT

| Type of Curve | No. of Curves Worse | | No. of Curves Unchanged | | No. of Curves Improved | |
|---|---|---|---|---|---|---|
| | Initial | Final | Initial | Final | Initial | Final |
| Lumbar | | | | 2 | 7 | 4 |
| Thoracolumbar | | 3 | 12 | 20 | 33 | 19 |
| Thoracic and lumbar | | 1 | 6 | 11 | 11 | 8 |
| Thoracic | | 2 | 2 | 3 | 6 | 2 |
| Total C | | 1 | | 1 | 3 | 1 |
| Total | 0 | 7 (9 per cent) | 19 (24 per cent) | 37 (47 per cent) | 59 (76 per cent) | 34 (44 per cent) |

FACTORS RELATED TO THE LOSS OF CORRECTION

Certain factors which might influence the amount of correction retained were investigated (Table V).

*Age of the patient at the time of fusion:* This obviously is of importance since progression is more likely to occur in patients who are actively growing. All but one of the patients with curves that became worse were from twelve to fourteen years old. Nearly a third of those who showed no change and almost half of those who remained improved were also fourteen years old or less.

*Duration of recumbency:* All of the patients with curves that became worse, a majority of the patients whose curves were unchanged, and most of the patients whose curves improved were recumbent for no more than four months. It appears, therefore, that the results obtained by four months of recumbent immobilization can be as favorable as those obtained by six months of immobilization.

*Length of time the jacket was worn:* The effect of this factor is difficult to analyze, for if a pseudarthrosis was present or if there was an obvious loss of correction, the jacket was commonly continued for more than the usual period of a year. Thus, as might be

TABLE IV

FINAL RESULTS IN SEVENTY-EIGHT PATIENTS FOLLOWED FOR AN AVERAGE OF FOUR AND ONE-TWELFTH YEARS

| Type of Curve | No. of Patients Worse | | | | |
|---|---|---|---|---|---|
| | Under 40 Degrees | 40 to 60 Degrees | 60 to 80 Degrees | Over 80 Degrees | Under 40 Degrees |
| Lumbar | | | | | |
| Thoracolumbar | | | | 3 | 8 |
| Thoracic and lumbar | | | 1 | | 2 |
| Thoracic | | | 1 | 1 | |
| Total C | | 1 | | | |
| Totals | 0 | 1 | 2 | 4 | 10 |
| | | 7 (9 per cent) | | | |

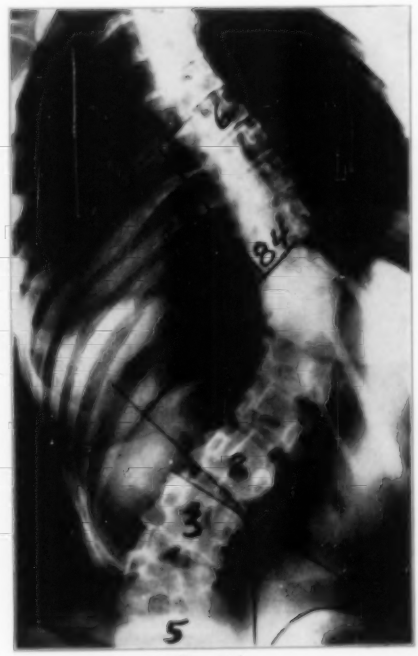


FIG. 3-A

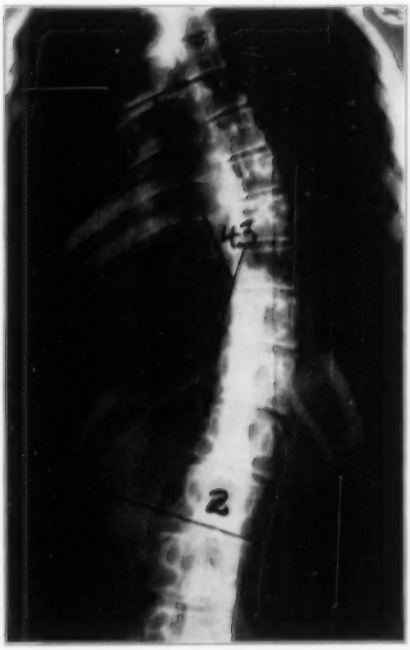


FIG. 3-B

Fig. 3-A: A thoracic and lumbar scoliosis in a twenty-year-old girl who had had a poliomyelitic attack six years previously. This preoperative roentgenogram was made with the patient sitting.

Fig. 3-B: Result nearly three years after the operation. The fused area extended from the seventh thoracic vertebra through the third lumbar vertebra. There had been an initial correction of 40 degrees and no loss had occurred during the last year of follow-up. No pseudarthrosis had ever been found. The patient was classified as improved.

expected, most patients with a progressive scoliosis (71 per cent) wore this rigid support for more than the usual length of time. The majority of the patients with unchanged curves (65 per cent) and, even more significant, 82 per cent of the patients who showed improvement wore the jacket for more than ten months after resumption of the erect posture.

TABLE IV

FINAL RESULTS IN SEVENTY-EIGHT PATIENTS FOLLOWED FOR AN AVERAGE OF FOUR AND ONE-TWELFTH YEARS

| No. of Patients Unchanged | | | No. of Patients Improved | | | |
|---|---|---|---|---|---|---|
| 40 to 60 Degrees | 60 to 80 Degrees | Over 80 Degrees | Under 40 Degrees | 40 to 60 Degrees | 60 to 80 Degrees | Over 80 Degrees |
| | | 2 | | 2 | 2 | |
| 6 | 3 | 3 | 6 | 7 | 6 | |
| 4 | 5 | | 1 | 2 | 5 | |
| 1 | | 2 | | | 2 | |
| | 1 | | | | 1 | |
| 11 | 9 | 7 | 7 | 11 | 16 | 0 |
| 37 (47 per cent) | | | 34 (44 per cent) | | | |

TABLE V

FACTORS IN ALTERATIONS IN AMOUNT OF CORRECTION

| | Worse (7 patients) | Unchanged (37 patients) | Improved (34 patients) |
|---|---|---|---|
| 1. Age of patient at time of fusion | | | |
| 14 years or less | 6 | 10 (27 per cent) | 14 (41 per cent) |
| Over 14 years | 1 | 27 | 20 |
| 2. Duration of Recumbency | | | |
| 4 months or less | 7 | 30 (81 per cent) | 22 (65 per cent) |
| Over 4 months | 0 | 7 | 12 |
| 3. Length of time jacket worn | | | |
| 10 months or less | 2 | 13 | 6 |
| Over 10 months | 5 (71 per cent) | 24 (65 per cent) | 28 (82 per cent) |
| 4. Type of graft | | | |
| Tibial | 5 (71 per cent) | 22 (59 per cent) | 18 (53 per cent) |
| Iliac | 2 | 10 | 13 |
| Both | 0 | 5 | 3 |
| 5. Pseudarthrosis | 5 (71 per cent) | 24 (65 per cent) | 15 (44 per cent) |

FIG. 4-A

FIG. 4-B

Fig. 4-A: A pseudarthrosis at the level of the twelfth thoracic vertebra (opposite *1*) is apparent on this roentgenogram made with the patient recumbent one year after the operation. This defect had been suspected six months after the fusion and was confirmed at operation. Repair by means of bank bone was done.

Fig. 4-B: This oblique roentgenogram, made two and one-half years after the operation, shows that the pseudarthrosis had persisted despite repair. The patient was symptom-free, however, and measurements indicated that there had been no further loss of correction. The spine had apparently become stable.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Oblique roentgenogram made eight months after the operation. No defect is apparent.

Fig. 5-B: Oblique roentgenogram made five months later (thirteen months after the operation). A defect had developed at the level of the first lumbar vertebra. The patient was symptom-free and the spine was grossly stable despite the presence of the pseudarthrosis.

Fig. 5-C: Oblique roentgenogram made eighteen months later (thirty-one months after the operation).

Although the patient was free from pain, a loss of correction of 15 degrees had occurred and the end result indicated that the curve had returned to its preoperative condition after the pseudarthrosis had closed spontaneously.

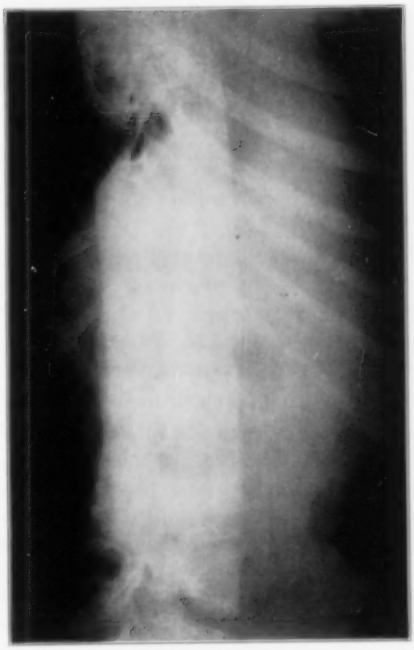

FIG. 5-C

*Type of graft:* There seems to be no clear indication from these cases that the type of graft employed, that is tibial, iliac, or a combination of the two, had any influence on the result.

*Pseudarthrosis:* As was expected, this complication occurred most frequently in the patients with the less satisfactory results. Pseudarthroses were found in 71 per cent of the patients whose curves became worse, in 65 per cent of those whose curves remained unchanged, and in 44 per cent of those who showed improvement. The subject deserves further analysis and, therefore, will be considered in more detail in the following section.

PSEUDARTHROSIS

A diagnosis of pseudarthrosis was made if a region of radiolucency was revealed by the anteroposterior roentgenogram, made with the patient sitting. When the roentgenographic findings were not definite, when there was pain, or when clinical examination revealed an obvious loss of correction, oblique roentgenograms were also made to confirm the diagnosis. In some instances lateral-bending and other special views were also made. It is realized that there is much disagreement concerning the reliability of roentgenographic methods of determining the presence of a pseudarthrosis; an attempt was made,

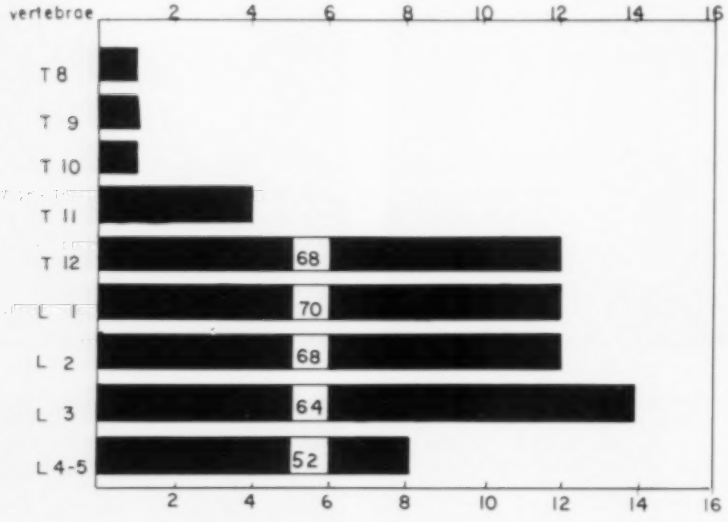


CHART I

Site and frequency of pseudarthroses. Figures indicate the number of times a specific vertebra was included in fusion.

therefore, to err on the positive side; a pseudarthrosis was assumed to be present if there was any doubt. In only eight patients (18 per cent) was surgical exploration performed and the diagnosis confirmed at the time of repair. Pain at the site of the pseudarthrosis was a rare symptom, occurring in only six (14 per cent) of the patients.

On the basis of the roentgenographic findings, a diagnosis of pseudarthrosis was made in forty-four (56 per cent) of the seventy-eight patients, including three with fractures of the graft. In sixteen cases there were two defects and in one case there were three defects. The earliest time after operation that a pseudarthrosis was noted was six months (Figs. 4-A and 4-B). In one case the pseudarthrosis was not visualized until three and a third years after the operation.

In twenty-four of the forty-four patients in whom pseudarthroses developed spontaneous healing occurred as evidenced by disappearance of the defects in the serial roentgenograms. The time required for healing varied widely. In one instance the defect disappeared four months after it was first seen, but more often many months elapsed before healing took place and during this time correction of the scoliosis was lost (Figs. 5-A, 5-B, and 5-C). In twenty patients, the defects remained visible for as long as eleven years.

Although a few of the spines with pseudarthroses were grossly unstable, as evidenced by roentgenograms made while the patient was bending sideways, a great many of these

spines appeared to be relatively stable. Repair of the pseudarthrosis was attempted by a second operation in only eight patients. In the majority, conservative methods of treatment were used, these patients being advised to avoid strenuous activities, to lie flat in bed twelve hours a day, and to wear the jacket constantly.

*Location of the pseudarthrosis:* The most common site for the defect was the lumbar spine, especially at the level of the third lumbar vertebra (Chart I). Because it was anticipated that there would be weakness at the junctions of the fusion areas where multiple-stage procedures had been performed, these areas were investigated. It was found that pseudarthroses had developed at these points in ten (23 per cent) of the forty-three pa-

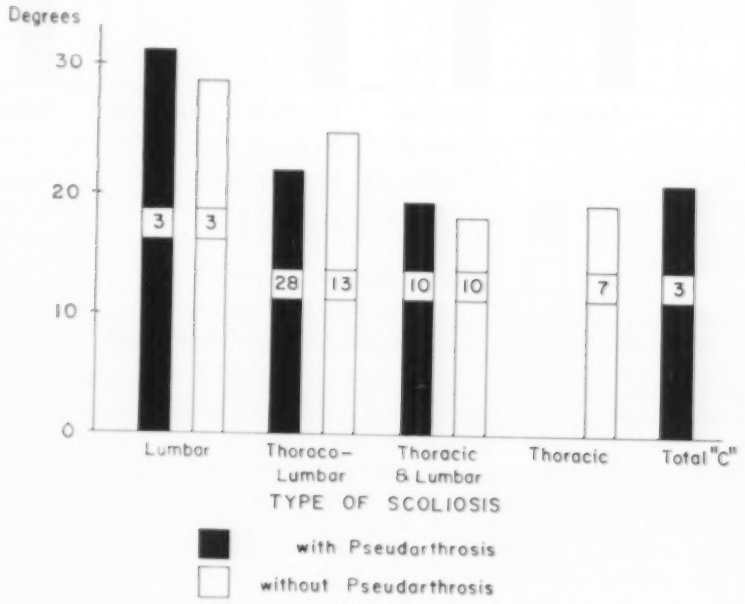


CHART II

Relationship of amount of initial correction to incidence of pseudarthrosis.

tients who had had multiple-stage procedures. The area about the apex of the curve, where the maximum stress might be expected to occur, was also observed particularly and pseudarthroses were found in this region in six (18 per cent) of thirty-four patients with lumbar, thoracolumbar, and total-C curves.

*Length of recumbency:* It is reasonable to expect that a graft composed of immature bone might be weak and more vulnerable to the formation of a pseudarthrosis if the patient resumed the erect position too soon. In thirty-six (61 per cent) of the fifty-nine patients kept recumbent for four months or less, a pseudarthrosis did occur in the graft. Pseudarthroses also developed in eleven (57 per cent) of the nineteen patients who were kept down between four and one-half and six months.

*Type of graft:* The incidence of pseudarthrosis in relation to the type of graft is of some interest. In thirty (71 per cent) of the forty-two patients in whom autogenous tibial strut grafts were used and in eleven (44 per cent) of the twenty-five patients in whom iliac grafts were used, defects developed. Of the small number (eleven) of patients in whom both types of graft were used, however, only three (27 per cent) had pseudarthroses.

*Effect of pseudarthrosis on amount of correction:* Although there seems to be no correlation between the amount of initial correction obtained and the later development of a

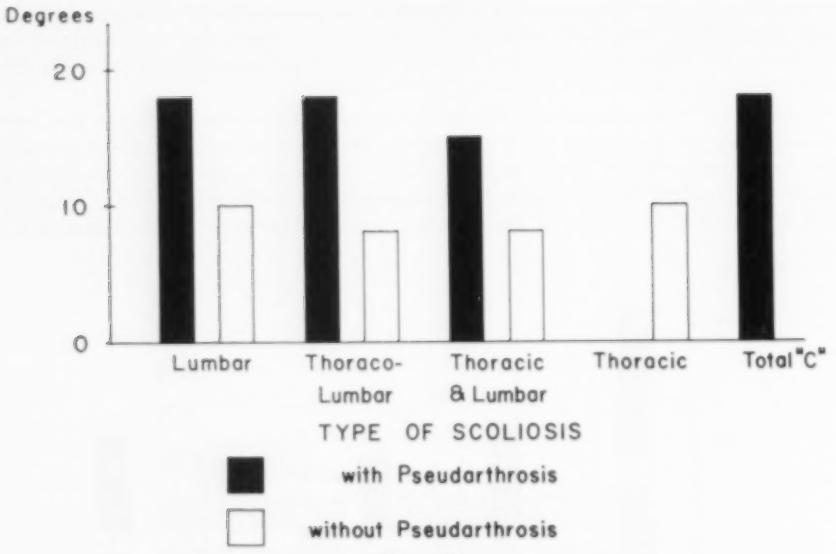


CHART III

Average total loss of correction with and without pseudarthrosis.

pseudarthrosis (Chart II), there is a definite correlation between the presence of a pseudarthrosis and the amount of correction retained (Chart III). As was expected, patients with apparent defects lost considerably more correction than did those without defects.

If the loss of correction were due to insufficient recumbent immobilization, the greatest loss would be expected to occur within the first six months after resumption of the upright position. In the patients with pseudarthroses, however, this was not the case. The amount of loss of correction increased after the initial six-month period and the greatest loss occurred after a year in every type of curve (Table VI). This same trend was also found in the patients without pseudarthrosis, except that in those with thoracic curves the loss of correction during the second six-month period following the resumption of sitting-up exceeded that occurring after twelve months.

Comparison of the final measurements of the curves in patients with and without pseudarthroses indicates that a pseudarthrosis is a potent factor in the production of

TABLE VI

AVERAGE LOSS OF CORRECTION IN DEGREES PER UNIT OF TIME AFTER RESUMPTION OF ERECT ATTITUDE

| Type of Curve | In Patients with Pseudarthroses | | | In Patients without Pseudarthroses | | |
|---|---|---|---|---|---|---|
| | By 6 Months (*Degrees*) | From 6 to 12 Months (*Degrees*) | After 12 Months (*Degrees*) | By 6 Months (*Degrees*) | From 6 to 12 Months (*Degrees*) | After 12 Months (*Degrees*) |
| Lumbar | 6 | 6 | 16 | 2 | 6 | 8 |
| Thoracolumbar | 3 | 6 | 12 | 1 | 3 | 4 |
| Thoracic and lumbar | 4 | 4 | 8 | 3 | 3 | 4 |
| Thoracic | | | | 1 | 10 | 6 |

TABLE VII

COMPARISON OF END RESULTS IN PATIENTS WITH AND WITHOUT PSEUDARTHROSIS

| Type of Curve | With Pseudarthrosis | | | Without Pseudarthrosis | | |
|---|---|---|---|---|---|---|
| | Worse | Unchanged | Improved | Worse | Unchanged | Improved |
| Lumbar | 0 | 1 | 2 | 0 | 1 | 2 |
| Thoracolumbar | 3 | 14 | 11 | 0 | 6 | 8 |
| Thoracic and lumbar | 1 | 8 | 1 | 0 | 3 | 7 |
| Thoracic | 0 | 0 | 0 | 2 | 3 | 2 |
| Total C | 1 | 1 | 1 | 0 | 0 | 0 |
| Totals | 5 | 24 | 15 | 2 | 13 | 19 |

unsatisfactory results. However, further progression of a curve may not occur despite the presence of a defect or, better still, the improvement may even be maintained, as was the case in about one-third of the patients with pseudarthroses (Table VII).

## SPECIAL CONSIDERATIONS

In paralytic scoliosis such factors as the patient's manner of walking and the distribution of muscle involvement are generally accepted as also contributing to loss of correction. Most of these factors are difficult to evaluate, however, for the amount of influence one may have is sometimes dependent upon the degree of severity of another. In the seven patients in whom the curves increased after fusion, an attempt was made to study some of these factors in more detail.

All seven patients were recumbent no longer than three and a half months following the second stage of their spine fusions. Each patient was able to walk although the degree of residual paralysis varied from almost none in two patients to severe paraplegia and spotty weakness of the trunk in two others. A marked limp due to weakness of the hip abductors exaggerated the curvature in two patients.

In all seven patients, the progression of the scoliosis was less during the first six months of sitting and standing than it was during the later months. Five of these seven had pseudarthroses and in these the greatest loss of correction occurred after a year. In two of these patients the defect remained visible for up to five years. In the two remaining patients who did not have pseudarthroses the curves were of the thoracic type.

The amount of correction obtained in these seven patients ranged from 13 to 30 degrees. The subsequent loss of correction was not related to the amount of initial correction. The worst results were associated with frank pseudarthroses but several factors may have combined to increase the deformity, as illustrated by the patient whose roentgenograms are reproduced in Figures 6-A and 6-B.

A comparison of the roentgenograms made preoperatively with the patient sitting and standing indicated that both the right thoracolumbar (fifth thoracic to second lumbar) and the left lumbar (third lumbar to fifth lumbar) curves were worse in the standing position; this was presumably caused by the presence of asymmetrical weakness of the trunk and hip musculature. Postoperatively, when standing and walking were resumed, considerable stress was exerted on the fused portion of the spine. A pseudarthrosis developed at the twelfth thoracic interspace ten months after operation and seven months after the patient was permitted to walk. As the result of the pseudarthrosis and the muscle imbalance, the pelvic obliquity increased. During the ensuing two and one-half years the pseudarthrosis healed but all correction was lost and the scoliosis became worse.

FIG. 6-A

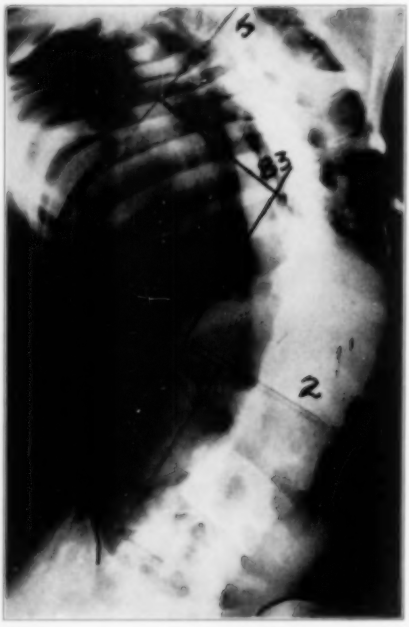

FIG. 6-B

Fig. 6-A: A thoracolumbar scoliosis in a fourteen-year-old boy who had had a poliomyelitic attack twelve years previously. This preoperative roentgenogram was made with the patient sitting.

Fig. 6-B: End result three years after the operation, shown in a roentgenogram made with the patient sitting. The curve had become worse and decompensation had occurred. The pseudarthrosis that had been present at the level of the twelfth thoracic vertebra had healed, however. The area fused extended from the fifth thoracic vertebra through the second lumbar vertebra.

In the two patients with thoracic curves who had no demonstrable pseudarthroses, the spine became decompensated and total curves developed. In one of these two patients the compensatory lumbar curve reversed its direction. In several other patients whose curves became worse, a sharply angulated curve developed above the area of fusion and, at the same time, there was a progressive lateral shift of the spine caudad to the fusion area (Figs. 7-A and 7-B).

In forty-four cases the fusion area did not include the fifth or the fourth and fifth lumbar interspaces. In two of these cases symptoms of a degenerated intervertebral disc developed at these levels five and one-half years and four and one-half years after operation respectively. Both patients were re-operated upon elsewhere and the fusion was extended into the sacrum by means of a prop-latch type of graft. In one patient, now forty years old, walking and stair climbing are performed better than before the additional fusion and in the other patient the spine is somewhat more stable as the result of the second procedure. Both patients have relief from pain.

*The length of the fusion:* It has always been difficult to determine how far the fusion should extend and to interpret the effect of the length of the fusion on the end result. In this study the extent of the fusion varied so widely that it was impossible to make a statistically significant analysis.

There were eighteen patients in whom the fusion extended two or more segments above and below the principal curve. Of these none were worse, eleven were unchanged, and seven were improved.

There were twenty-two patients in whom the fusion failed to include all of the

TABLE VIII

COMPARISON OF LENGTH OF FUSION AREA IN PATIENTS WITH "UNCHANGED" AND "IMPROVED" RESULTS

| Type of Curve | Unchanged (37 Patients) | | Improved (34 Patients) | |
|---|---|---|---|---|
| | Area Adequate* | Area Inadequate | Area Adequate | Area Inadequate |
| Lumbar | 2 | 0 | 4 | 0 |
| Thoracolumbar | 16 | 4 | 15 | 4 |
| Thoracic and lumbar | 7 | 4 | 2 | 6 |
| Thoracic | 3 | 0 | 2 | 0 |
| Total C | 1 | 0 | 0 | 1 |
| Totals | 29 | 8 | 23 | 11 |

* Adequate means that the fusion area included at least as many segments as were present in the main curve. Inadequate means the fusion area included less segments than there were in the main curve.

main curve by two or more segments. Of these one was worse, fourteen were unchanged and seven were improved.

There were only four patients in whom the fusion included one segment above and one below the primary curve. In all four the curvatures were unchanged.

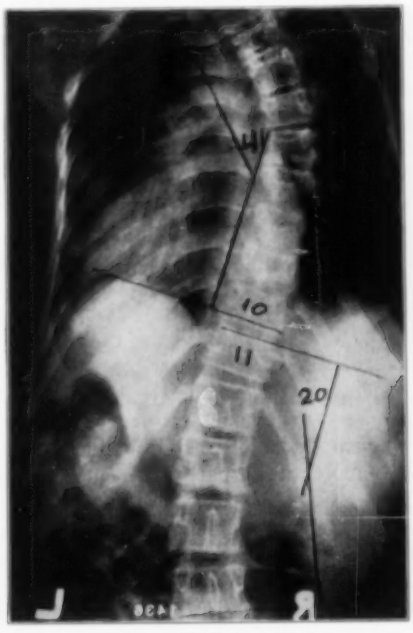


FIG. 7-A

FIG. 7-B

Fig. 7-A: Progressive thoracolumbar scoliosis in a sixteen-year-old boy. This preoperative roentgenogram was made with the patient sitting, eight years after the onset of paralysis.

Fig. 7-B: Roentgenogram made with the patient sitting, nine years after the operation. Decompensation had occurred, and there was a sharply angulated curve above the fusion area which extended from the sixth thoracic vertebra through the fifth lumbar vertebra. Note that a pseudarthrosis is still apparent at the level of the third lumbar vertebra.

TABLE IX

ANALYSIS OF LENGTH OF FUSION AREA IN PATIENTS WITH "WORSE" RESULTS

| Type of Curve | Extent of Curve | Area Fused | Adequacy of Length of Fusion |
|---|---|---|---|
| 1. Thoracolumbar | T6 to L2 = 8 segments | T9 to L2 = 5 segments; later extended to T6 and L5 | Initial length inadequate |
| 2. Thoracolumbar | T4 to L2 = 10 segments | T6 to L5 = 12 segments | Total length adequate; question selection of limits |
| 3. Thoracolumbar | T5 to L2 = 9 segments | T5 to L2 = 9 segments | Total length adequate |
| 4. Thoracic and lumbar | T3 to L4 = 13 segments | T4 to L4 = 12 segments | Questionable whether total length adequate |
| 5. Thoracic | T4 to L1 = 9 segments | T3 to L1 = 10 segments | Total length adequate |
| 6. Thoracic | T4 to T12 = 8 segments | T4 to L1 = 9 segments | Total length adequate |
| 7. Total C | T7 to L4 = 9 segments | T8 to L4 = 8 segments | Total length inadequate |

In the remainder there was a great variety of combinations. In some of the patients with the thoracic and lumbar type of curve fusion failed to include from one to seven vertebral segments at the cephalad end of the curve or extended from one to four segments beyond the cephalad end of the curve but failed to include from one to four segments at the caudad end. In others the fusion included the whole of the cephalad end of the main curve and extended one to three segments beyond the lower end.

The caudad limit of the fusion area was influenced by the fact that we were reluctant to include the sacrum in the original fusion area. Our reluctance to do this was based on the assumption that fusion of this area would impede walking. However, in two patients in whom it became necessary to extend the fusion into the sacrum in a second procedure because of the development of lumbosacral pain, no interference with walking or sitting was noted. In fact both patients were improved by the later extension of the fusion.

In studying the cephalad extension of the fusions, it was found that none of the patients in this series had main curvatures which extended further cephalad than the second thoracic vertebra, although, of course, there were compensatory curves extending into the cervical region. Unfortunately the roentgenograms often did not include all of the cervical region and hence it was impossible to measure this part of the curve in many cases.

There were five patients with thoracic curves extending as high as the third thoracic vertebra. Among these there were two whose fusions extended to the second thoracic vertebra or one segment beyond the curve. The curvatures of both of these patients were unchanged following treatment. Another of these five patients had a fusion which included all of the segments in the primary curve except for one vertebra at the top. In this case a pseudarthrosis developed and the end result was one of the worst in the series (Fig. 7-B). In one of the remaining two cases data on the cephalad extension of the fusion were not available. In the other the fusion failed to include the uppermost two segments as well as three vertebrae at the caudad end; yet the curvature in this case was improved.

When the final results were correlated with the extent of the fusion (Table VIII), it

was apparent that among the thirty-four patients whose curves were improved, there were eleven (32 per cent) in whom the fusion was considered inadequate (the fusion did not include the whole extent of the fixed curve). Among the thirty-seven patients whose curves remained unchanged, eight (22 per cent) had inadequate fusions. Among the seven patients whose curves became worse, three had inadequate fusions, and those with the longest fusion areas had some of the worst results (Table IX). These findings are in accord with those of Ponseti and Friedman.

In this small series no valid conclusions with regard to the influence of the length of the fusion can be drawn. It is clear, however, that the findings of this study do not lend support to the concept that in paralytic scoliosis the fusion area should extend one or more segments above and below the principal curve, for 32 per cent of the patients whose curves were improved had fusions which did not even include all the segments within the main curve.

In general, those patients whose fusion included all of the principal curve had better results than those whose fusion did not include the entire curve. Nevertheless, it would appear from this study that other factors, such as the development of a pseudarthrosis and the type of postoperative support, have more influence on the final result than does extension of the fusion beyond the principal curve.

## DISCUSSION

As the study was continued and as certain trends became evident, changes were made in the routine treatment of patients with paralytic scoliosis.

The data indicate that the performance of fusion in children as young as ten years of age need not have unfavorable results, especially if the principle of fusing the minimum area is accepted. Hence, if, despite adequate conservative care, the curve continues to progress, fusion should not be delayed until the patient is fourteen or sixteen years of age.

Alterations have been made in the surgical technique. All the spinous processes are now removed in order that the onlay grafts may be placed in closer contact with the underlying decorticated laminar bed. Iliac bone is preferred as the grafting material, but often in young patients, and especially in those with atrophic bones, only tibial bone is available. In these cases, the struts are now cut into thin strips which are about three-sixteenths of an inch thick and one-eighth of an inch wide and which extend the length of the fusion area. Three to five of these strips are laid down in the graft site.

It is believed that there is no apparatus which can maintain complete correction of a structural paralytic scoliosis when the patient is erect. When the patient is recumbent, however, the Milwaukee frame, which produces a combination of distraction and of properly placed counter pressure, often does measurably improve some curvatures. This apparatus is least effective with lumbar curves, but even with these benefit may occur.

The length of time the patient is immobilized in a recumbent position is important for both physiological and financial reasons. This period should, of course, be kept as short as possible. The findings in the author's series suggest that this factor is less important than others in relation to the final results obtained. For example, 80 per cent of the patients who showed no progression and 64 per cent of the patients who retained much of the initial correction were all recumbent for only four months or less. Furthermore, although the incidence of pseudarthrosis was greatest in the group of patients who were among the first to begin sitting, this incidence was only 14 per cent greater than that in the rest of the patients. Before permitting a patient to resume the erect position, oblique roentgenograms should be made. If these roentgenograms show that the graft is obviously of poor quality, a longer period of recumbency is advisable. If a definite pseudarthrosis is revealed, the plan of treatment must be modified accordingly. It should be emphasized, however, that the greatest loss of correction in all cases occurred after the first six-month period following the resumption of sitting and standing.

There is strong evidence that a rigid support should be worn by the patient for considerably more than a year following the operation. According to the author's current routine a rigid support is continued for about two years following the assumption of the erect position. For patients with thoracic or thoracolumbar curves the use of a head-traction apparatus attached to a cellulose-acetate jacket may help control the cervicothoracic portion of the deformity.

Although the incidence of pseudarthrosis in this series was high (56 per cent of seventy-eight patients), the incidence reported by Ponseti and Friedman was higher, with 70 per cent of forty-three paralytic patients having a pseudarthrosis. On the other hand, the incidence reported by Cobb was lower, with only twelve (13 per cent) of ninety patients having a pseudarthrosis. The fact that a defect was not noted until as long as three years after the operation in one case in the author's series is most important, and it is also significant that in a number of patients, the spine was grossly stable despite the presence of an obvious defect, as shown by roentgenograms (Figs. 5-A through 5-C).

For the treatment of a pseudarthrosis, the following routine is recommended. As soon as the defect is discovered, the approximate loss of correction should be determined by means of roentgenograms made with the patient bending laterally in the recumbent position. If the defect is considerable and hypermobility is definitely present, surgical repair should be done. If the amount of correction retained is commensurate with a satisfactory outcome, however, the patient should simply be instructed to limit the time he is not recumbent and to return at two-month intervals to check on the progress of his curvature by means of roentgenograms made in the erect position and in the oblique projections. It is well to remember that in the author's series the outcome in twenty of the forty-four patients with pseudarthroses was a stable, painless spine in which loss of correction did not continue. Furthermore, in fifteen of these patients correction was retained and in only four of these fifteen patients was it necessary to perform surgical repair with additional correction.

## SUMMARY

1. In a series of seventy-eight patients with poliomyelitic scoliosis treated by spine fusion, the final results were as follows: 9 per cent became worse; 47 per cent showed no change; and 44 per cent were improved. The average follow-up period in this series was four and one-twelfth years.

2. In forty-four patients (56 per cent) there appeared to be a pseudarthrosis. Only 14 per cent of these patients had pain, however, and only 18 per cent were re-operated upon. About 45 per cent of the defects remained visible roentgenographically for as long as ten years.

3. In all patients the greatest loss of initial correction occurred at least six months after sitting and standing was resumed, and in most patients it occurred after a year.

4. It is recommended that in the treatment of patients with paralytic scoliosis, iliac or thin tibial grafts be used, that four months of recumbent immobilization be considered sufficient, and that the patient wear a rigid cellulose-acetate jacket for at least two years after the upright position is permitted.

NOTE: Grateful acknowledgment is made to Dr. C. E. Irwin for his advice; to Mr. Richard McClure, Miss Muriel Driver, O.T.R., and Dr. John M. Herring for their assistance with the illustrations; and to Miss Bette Jane Snyder for preparing the manuscript.

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## DISCUSSION

Dr. John H. Moe, Minneapolis, Minnesota: Dr. Gucker's frank presentation illustrates the problems which beset us when we treat paralytic scoliosis and calls to our attention the need for improving our results.

The classification of end results in patients with scoliosis is difficult, for I would consider it inaccurate to classify the results entirely according to measurements made on the roentgenograms. It is the patient's cosmetic and functional improvement which is paramount, and I have seen a substantial improvement in appearance and function occur in patients whose curves were permanently reduced only 20 degrees (from 80 to 60 degrees) or even less.

A progressive deforming curve should be treated by correction and fusion as soon as the condition exists regardless of the age of the patient. If one delays treatment, the opportunity for obtaining an excellent cosmetic improvement will have passed and one will be faced with the problem of salvaging some correction in a marked structural curve. Contrary to the author's recommendations, however, in the young patient, and especially in the poliomyelitic patient, one must fuse a longer, and not a shorter, area.

Seldom, if ever, does bending occur in a fused curve if the area has become solidly fused, if the fusion is sufficiently long, and if there is no defect or pseudarthrosis.

Pseudarthroses in spines that have been fused are more common than we care to admit and are a prime cause of lack of retention of the correction. The large majority can be detected by careful studies of oblique roentgenograms.

When reports indicate the presence of pseudarthroses in 56 per cent of patients with fused curves, as in the author's series, or of an even higher percentage, as in the series of Ponseti and Friedman, it well behooves us to stop and reconsider our methods of attempting fusion of the spine.

In closing this discussion I should like to bring to you my own experience with the same problem. Since 1948 I have had the opportunity of personally fusing or of supervising the fusion of 225 curvatures. In this series the fusions were at first done much as they are done in the author's series, by adding homogenous or bank bone to the decorticated and flaked-up laminae. When the first fifty fusions were evaluated, a shockingly high percentage of pseudarthrosis was found—close to 50 per cent.

As time went on, a wider bone exposure and a more meticulous removal of ligamentous tissue were combined with the interlocking of attached laminar fragments and the addition of large amounts of homogenous bone. The percentage of pseudarthroses dropped gradually but the complication still remained a severe problem.

Two years ago a facet-fusion technique was adopted and has been done in over 100 patients with scoliosis. Forty-five of these patients have now been without external support for a year, and only four of them have shown evidence of a pseudarthrosis. Thus the incidence of pseudarthroses has been reduced from 50 per cent to somewhat under 10 per cent by a change in the method of fusion. In my opinion, the facet fusion, when carefully performed, is the most important feature of the operation.

Dr. Joseph C. Risser, Pasadena, California: Dr. Gucker's two-fold goal of preventing an increase in the deformity and of obtaining stability in the spine is a worthy one. In his attempts to prevent the curve from becoming worse, however, I would say he started his treatment late, for at the time of operation, the curves in his patients were already severe. At some point the spines in these patients were straight, and if the presence of the deformity had been observed early, while the curve was still increasing, the spine could have been more nearly straight at the conclusion of the treatment. I think our biggest problem is to have the courage to operate upon the spine while the curvature is still mild instead of waiting until it becomes severe.

Dr. Gucker reports that half of his patients were fifteen years of age or older. In these patients, growth of the vertebrae would have been complete and, therefore, the curvature of the spine would have become static, making unnecessary any treatment to prevent further increase of the deformity.

Dr. Gucker's second objective in the treatment of patients with paralytic scoliosis is to obtain stability of the spine. Stability is most easily produced in a spine that is straight, and, therefore, the obtaining of as much correction as possible before the performance of fusion is an excellent means of producing greater stability.

The greatest percentage of correction always occurs in the patients whose initial curves were the least severe, and, therefore, the decision to perform surgical correction should be made as early as possible before the deformity becomes severe. This may mean fusing the spine in very young patients, but, as the author has pointed out, youth is no contra-indication to the performance of fusion.

All surgeons have had some bad results in the treatment of scoliosis, and Dr. Gucker was very honest in describing his. I think one of the chief reasons for failure to achieve a good result is not obtaining a good

correction before the operation, for correction should come before the fusion rather than afterward. In Dr. Gucker's series the correction often appeared ten days to two weeks after the operation. It is imperative that the surgeon be able to outline the area of fusion before performing the operation. This procedure frequently cannot be carried out unless the spine is in a corrected position, however, and if the surgeon waits until after the operation to obtain correction, he has missed his opportunity for making a really accurate analysis of how long the fusion should be.

In Dr. Gucker's series the average length of postoperative immobilization in a corrective cast was three or four months. If correction is to be permanently maintained, the immobilization must be continued until the involved area is solidly fused, that is, not just for a month but for as long as is indicated by roentgenographic evidence, whether it be six, eight, or ten months. A removable jacket is not an adequate substitute for a corrective jacket, and every new cast that is applied must be corrective as well as supportive. In this way loss of correction of the deformity may be prevented.

The obtaining of a good fusion is important in the maintaining of correction, and I was pleased to learn that Dr. Moe's results improved when he used a facet type of fusion. The closer the surgeon can place the graft to the point of contact between the vertebrae, the less extra bone he has to use, as Dr. Moe has pointed out and as Dr. Hibbs has taught. For this reason the facet type of fusion does not require the use of a large amount of extra bone.

If the fusion does not cover the full extent of the curve, the deformity will recur, not only in patients who are through growing but also in those who are still growing. Furthermore, in the latter patients the deformity may increase, and I notice that in Dr. Gucker's series the deformity did increase in some of the children who were fourteen years old or younger. In these patients there was still the potential for the deformity to increase and, therefore, it was logical they should be the ones who became worse.

It is impossible to eliminate the problem of pseudarthrosis altogether, for it is impossible to control all the variables that are involved. The surgeon can control the length of the period of immobilization and he can control the amount of bone used in grafting, but he cannot control the metabolism of the patient, a factor which is important in the development of pseudarthroses. For example, if the patient doesn't eat the proper food, his bone growth will be less satisfactory than it would be otherwise. Under the present circumstances, the surgeon is not as much at fault if a pseudarthrosis develops as he is if he fails to recognize and repair this defect before loss of correction occurs.

DR. GUCKER (closing): I agree entirely with Dr. Moe's statement that some of the benefits obtained in patients with scoliosis cannot be discerned by means of roentgenograms. In our series, however, we have had to use roentgenograms as a means of comparison, for during the last three years we have not been able to see all our patients personally.

I wish to stress the fact that, according to the reports in the literature, the incidence of pseudarthrosis is higher in patients with paralytic scoliosis than it is in patients with any other form of scoliosis. I hope that in Dr. Moe's new series, the results with respect to this factor will be as good in the paralytic patients as they are in patients with idiopathic scoliosis.

The loss of correction which occurred in our patients during the second year and sometimes even during the third and fourth years after the operation was disturbing. I hope that the patients upon whom Dr. Moe performed facet fusions almost a year and a half ago will continue to show as much retention of correction as they have shown up until now.

The main purpose of this paper is to present the data we have studied, and we are more interested in asking questions than in suggesting conclusions. One question we are particularly interested in is how old the patient must be before he can be operated upon. May he be operated upon when he is only three years of age, or should the surgeon wait?

# Intertrochanteric and Subtrochanteric Fractures of the Femur in the Negro * †

BY LOUIS R. ROBEY, M.D., ST. LOUIS, MISSOURI

*From the Department of Surgery, Homer G. Phillips Hospital, St. Louis*

This paper presents an unselected consecutive series of ninety-nine cases of intertrochanteric and subtrochanteric fractures of the femur in the Negro. All of these patients were treated in this Hospital during the seven-year period from 1946 through 1952. Fractures which involved only the greater or the lesser trochanter are not included.

Cleveland and his colleagues and Lewis stated in the conclusions of their frequently quoted articles that intertrochanteric fractures of the femur are rare in Negroes; we do not believe that this fracture is rare but, instead, that it is usually not reported.

Siler and Caldwell, however, included forty-four Negro patients in their five-year

TABLE I

CAUSATIVE INJURY, AGE AND SEX INCIDENCE OF THESE CASES

| Causative Injury | Sex | | | Average Age | |
|---|---|---|---|---|---|
| | Male | Female | Total | Male | Female |
| Falls: | | | | | |
| Simple falls in the home | 9 | 36 | 45 | 74 | 73.7 |
| Simple falls outside home (including falls on ice) | 8 | 3 | 11 | 59.8 | 58 |
| Downstairs | 9 | 5 | 14 | 62.8 | 73.4 |
| Knocked down | | | | | |
| At home | 1 | 4 | 5 | 60 | 70 |
| Outside home | 1 | 1 | 2 | 72 | 77 |
| Fall from height | 13 | 2 | 15 | 35.9 | 36.5 |
| Automobile Accidents | | | | | |
| Passenger | 2 | 1 | 3 | 34.5 | 50 |
| Pedestrian | 0 | 2 | 2 | | 54.5 |
| Miscellaneous | | | | | |
| Struck by push cart | 1 | 0 | 1 | 75 | |
| Struck by flying buzz saw | 1 | 0 | 1 | 52 | |

analysis of 103 cases of intertrochanteric fractures of the femur at the Cincinnati General Hospital; in the author's series, ninety-nine Negro patients with intertrochanteric fractures were treated at the Hospital over a seven-year period, as compared with only seventy-four cases of intracapsular fractures of the femur.

In the author's series there were forty-five males and fifty-four females. The ages ranged from twelve to 101 years, the average age for the series being sixty-four years. The average age for the male group was 55.7 years, whereas in the female group the average age was 70.7 years. The great difference in the average age is due to the high incidence of this type of fracture in young males subsequent to severe trauma, and a high incidence in old females as the result of simple injuries in the home.

Of the total number of patients, 65 per cent sustained the injury in the home, and 70 per cent of these were injured in simple falls. There was a high incidence of delayed

* Award-winning paper of the St. Louis Medical Society Essay Contest, December 15, 1953.
† Read at the Annual Convention of the National Medical Association, Washington, D. C., August 13, 1954.

TABLE II
ANALYSIS OF MORTALITY RATE

| Period of Hospitalization | Deaths in Cases with Operation* (No.) | (Per cent) | Deaths in Cases without Operation (No.) | (Per cent) |
|---|---|---|---|---|
| First month | 9 | 14.7 | 13 | 33.0 |
| Second month | 2 | 3.3 | 4 | 10.6 |
| Third and fourth months | 0 | 0 | 0 | 0 |
| After fourth month | 1 | 1.6 | 3 | 7.6 |
| Total no. of deaths in hospital | 12 | 19.6 | 20 | 51.2 |

* Percentages are calculated on a basis of sixty-one cases with operation, instead of sixty as in Table IV, since one patient (Case 2, Figs. 4-A to 4-D) received secondary operative treatment after eight months of conservative treatment in the hospital.

examination and treatment. Because of the trivial nature of the accident causing the injury, many patients belittled their condition, calling it a bruise or a sprain, and remained too long at home in bed before seeking treatment. It is usually recommended that surgery be performed within forty-eight hours of injury for optimal results; however, in this series, the average time before patients entered the Hospital was seventy-eight hours after injury. It is significant that the average period of time elapsed before admission was forty-four hours among the survivors, and, in the group that died, seven and one-half days after injury. This inexcusable delay is obviously reflected in the mortality rate (Table II).

The vast majority of these patients were indigent. Consequently, the incidence of malnutrition, dehydration, chronic anaemia, and other untreated disorders was very high. Of these ninety-nine patients, only five were admitted who did not have one or more of these major disorders concomitantly. At the time of admission to the Hospital fifteen of these patients had other fractures, eight had cerebral concussion, and one a basal skull fracture; thirteen had crippling arthritis, one pyogenic arthritis of the involved hip. Among them were nine hemiplegics and two paraplegics. There were forty patients with hypertension, twenty-three with calcified femoral vessels, ten with cardiac decompensation; thirteen suffered from senile psychosis, six from inanition and marked dehydration; two were in diabetic coma, and six in alcoholic stupor. Seven patients had diabetes mellitus, five had decubitus ulcers, two had bronchopneumonia, and one patient each had an incarcerated hernia, epilepsy, pulmonary tuberculosis, cirrhosis of the liver, and an intestinal obstruction. One was an attempted suicide.

During the early years of this study, the majority of the patients treated by internal fixation were young, "good-risk" patients. Elderly, "poor-risk" patients were treated mainly by the so-called conservative methods (such as traction, casts, and Wilkie boots). Our present management is just the reverse, as we now apply to trochanteric fractures of the femur the concept of Key concerning intracapsular fractures, that the "truly conservative method of treating a fracture through the neck of the femur is to operate", especially in the aged (Charts I and II).

There are, however, exceptions to this practice. We do not routinely operate in every case of intertrochanteric fracture of the femur, because, in some cases, the condition of the patient upon admission to the Hospital is too poor for anything except supportive treatment. In other cases, there may be comminution to such an extent that very little could be

Chart I: A year-by-year analysis of the mortality rate in intertrochanteric fractures in terms of percentages of operative cases.

Chart II: A comparison of the mortality rate in operative and non-operative cases, together with the age distribution by decade. The total number of cases in each decade is recorded below the corresponding point in the curve.

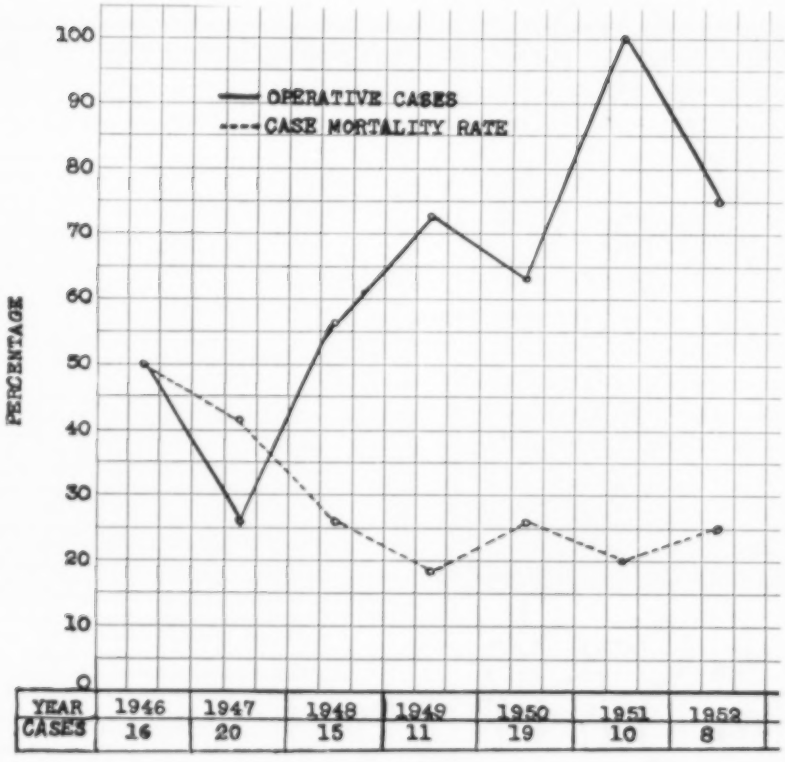


CHART I

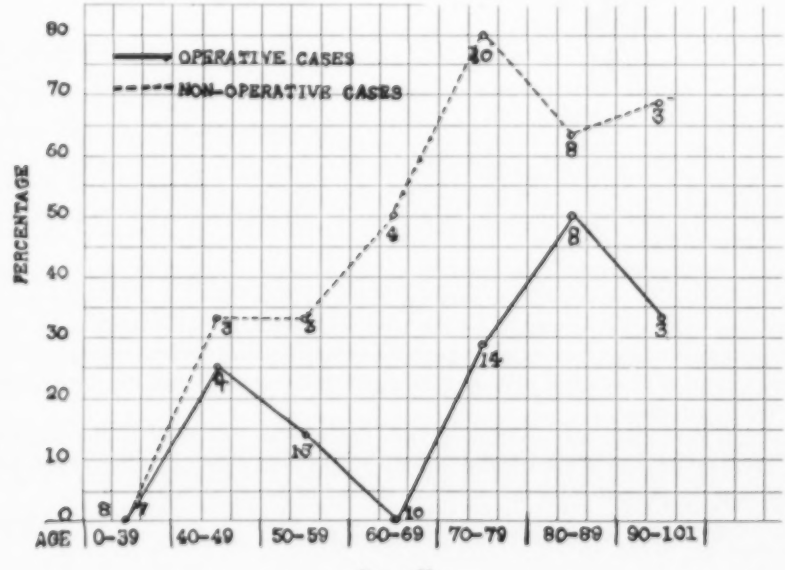


CHART II

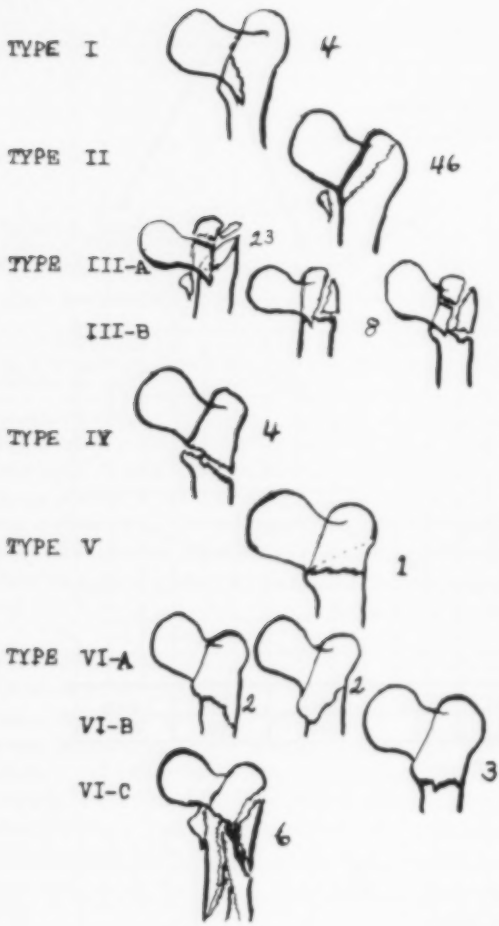


FIG. 1

Fig. 1: *Type I*, basal (four cases). Extracapsular fracture at the base of the neck of the femur, with or without involvement of the greater or lesser trochanter. In this type, the calcar femorale is usually impacted into the soft cancellous portion of the trochanteric region of the femur with resulting coxa vara deformity.

*Type II*, intertrochanteric (forty-six cases). A linear break extending along or parallel to the intertrochanteric line. The lesser trochanter is usually detached in this type.

*Type III*, comminuted intertrochanteric (thirty-one cases). *Type III-A* (twenty-three cases). The comminution involves mainly the proximal portion of the trochanteric region, with a part of the trochanteric region remaining attached to the shaft of the femur. *Type III-B* (eight cases). This is basically a subtrochanteric fracture with comminution of the trochanteric region.

It is important to differentiate between these two types of comminuted intertrochanteric fractures of the femur. The internal fixation is frequently different. The incidence of medial migration of the distal fragment, protrusion of the nail, shortening, and malunion is higher in the "B" group. This type may also be produced as an operative complication of a Type II or Type III-A fracture.

*Type IV*, reverse intertrochanteric or oblique subcervical [5] (four cases). The fracture line begins at the lower border of the base of the femoral neck and extends obliquely downward and outward, bisecting the intertrochanteric line at almost right angles.

*Type V*, pertrochanteric (one case). Transverse fracture between the trochanters of the femur.

*Type VI*, subtrochanteric (thirteen cases). Fracture at the level of or just below the lesser trochanter. *Type VI-A*, oblique (four cases). *Type VI-B*, transverse (three cases). *Type VI-C*, comminuted (six cases). The fracture line extends down the shaft and often upward into the trochanteric region.

hoped for by internal fixation alone. Prolonged postoperative immobilization, of a duration equivalent to that in non-operative treatment, would also be necessary. If this situation is anticipated from the preoperative roentgenograms, surgery is ill-advised, since it would be an added risk. Extensive comminution of the shaft of the femur which was not evident in the preoperative roentgenographic examination may be encountered during surgery.

Good roentgenographic visualization of the femoral head, neck, and trochanteric region is essential for successful hip surgery. Much time and work is saved and many bad nailings may be avoided by waiting for the x-ray technician or the roentgenologist to make the proper adjustments; it is better to have the technician make repeat roentgenograms, if necessary, than to be satisfied with poor roentgenograms; good lateral roentgenograms are particularly important.

Sodium pentothal, nitrous-oxide-oxygen anaesthesia was used in the majority of cases. Local infiltration of the fracture site with 1 per cent novocain solution just prior to transporting the patient from the ward has the following advantages:

1. There is minimal pain and shock of movement when the patient is moved from bed to the stretcher to the operating table and then placed in the proper position.

2. Preoperative traction is permitted. This usually decreases manipulative reduction

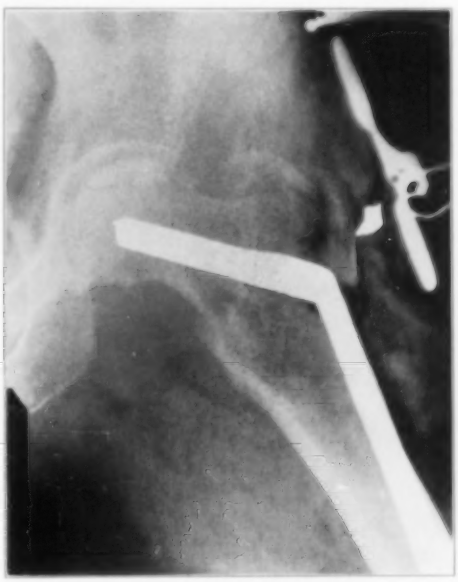

FIG. 2-A

FIG. 2-B

Fig. 2-A: An intertrochanteric fracture of the femur complicated by fragmentation of the lateral portion of the trochanter at the time of surgery.

Fig. 2-B: The fragments were stabilized by superimposing an ordinary bone plate upon the plate extension of the nail with excellent results.

to a minimum, and minor adjustments of position of the fragments may frequently be made without the definitive anaesthesia.

3. Pain at the fracture site is greatly reduced and a smaller quantity of anaesthetic is generally required.

4. The duration of the anaesthesia is also greatly reduced, since some preoperative manipulation has been made possible by the local anaesthetic and since the patient is in the optimal relaxed state preoperatively. This is extremely important in the aged.

The patient is placed upon the orthopaedic table with the involved hip in a position of slight flexion and abduction, and in a neutral or slightly laterally rotated position. In contrast to its effect in fractures of the neck of the femur, medial rotation may cause the fragments of an intertrochanteric fracture to be separated in some cases. The guide-wire Neufeld-nail technique was used almost routinely in the patients treated by internal fixation.

The outer cortex of the femur in the trochanteric region is very thin and fragile and may become fragmented easily during the introduction of the nail; this occurred in eight patients in this series. In effect, this operative complication converts the trochanteric fracture into a subtrochanteric fracture, and demands special attention. If the fracture line is at the angle of the nail, there is danger of medial migration of the distal fragment caused by the strong pull of the adductor muscles, or of bending and subsequent breaking of the nail caused by the natural tendency of the tendo fasciae latae, the gluteal muscles, the iliopsoas, and the adductors to pull the extremity into a position of coxa vara. Prevention of these complications necessitates additional fixation. This fixation may be applied externally by traction or a cast, or the fracture may be internally stabilized by superimposing an ordinary bone plate upon the plate extension of the nail (Figs. 2-A and 2-B).

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 1. The patient was a woman, thirty-four years old, who had attempted to commit suicide by taking poison and jumping from a second-story window. She sustained an intertrochanteric fracture of the femur which was treated by skeletal traction as she had refused open operation.

Fig. 3-B: Eight months later there was a coxa vara deformity, medial migration of the distal fragment, marked limitation of function, and non-union. Unstable fibrous union was found at surgery. A Neufeld nail was inserted and bone grafts were placed about the fracture.

FIG. 3-C

FIG. 3-D

Fig. 3-C: The patient resumed full weight-bearing two months postoperatively (upon her own advice), which caused the nail to break. She refused additional surgery.

Fig. 3-D: Four years later there was extensive resorption of bone about the nail, four inches of shortening, false joint motion, and the patient was obliged to use crutches.

### POSTOPERATIVE MANAGEMENT

Postoperatively, antibiotics are given routinely for four to seven days. Wheel-chair

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 2. A man, sixty-four years old, had sustained a stable, undisplaced intertrochanteric fracture of the femur in a simple fall. The fracture line was barely visible on the admission roentgenogram. He was treated by Russell's traction.

Fig. 4-B: After two months the fracture line was more prominent.

FIG. 4-C

FIG. 4-D

Figs. 4-C and 4-D: After four months and seven months obvious non-union was present. Note the smooth sclerotic prominent edges of the fracture lines and the calcified femoral vessels. Although twenty-three patients in this series had calcified femoral vessels, there was non-union in only one of these patients.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 3. Roentgenogram of the hip of a man, fifty-two years old, who was struck by a flying buzz saw and sustained a compound subtrochanteric fracture with marked soft-tissue destruction. Débridement and primary closure were performed, and the fracture was treated by balanced skeletal traction.

Fig. 5-B: Upon discharge after four months, there was medial migration of the distal fragment and coxa vara, and the fracture line was visible.

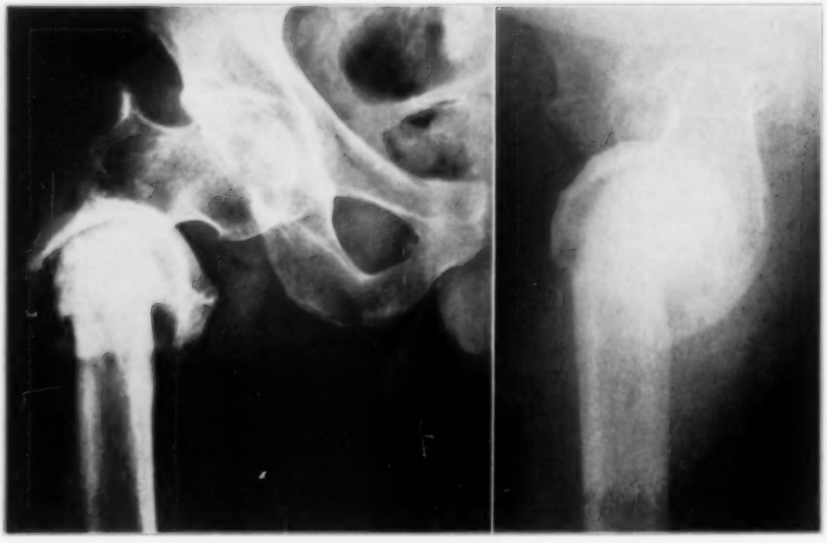

FIG. 5-C

The patient did not return for follow-up, but was located for this study five years later. At that time, there was non-union, false-joint formation in the subtrochanteric region, with a 30-degree range of motion in the false joint.

FIG. 6-A

FIG. 6-B

Fig. 6-A: In this case, a 101-year-old man had sustained a comminuted intertrochanteric fracture of the femur following a simple fall at home one day prior to admission. There was associated advanced arteriosclerosis with malnutrition, dehydration, and extensive scabies.

Fig. 6-B: Twenty-four hours after admission, a Neufeld nail was inserted under local anaesthesia supplemented with one-fourth per cent pentothal (100 milliliters or 0.25 gram was given). The patient had an uneventful operative course but died on the thirteenth postoperative day with right-lobar pneumonia.

ambulation is started in one to three days. No postoperative traction or external fixation is usually employed. However, when there is doubt concerning the stability of the internal fixation, we do not hesitate to use traction for three to four weeks, especially in the younger patients. Fortunately, most of the badly comminuted fractures occurred in the younger groups.

The patients who have had no complications are usually ready for discharge in ten to fourteen days, if home conditions are satisfactory. Early use of crutches is encouraged if the patients can manage them. Weight-bearing is not advocated until the fourth to the sixth month. The time required for healing of these fractures varied from three to five months, except in the six cases of non-union, which may be summarized as follows:

1. Secondary surgery was performed eight months after the original injury (Figs. 3-A through 3-D).

TABLE III

ANALYSIS OF END RESULTS AND ORTHOPAEDIC COMPLICATIONS IN THE CASES WITH OPERATION

| | Type of Fracture | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | III-A | III-B | IV | V | VI-A | VI-B | VI-C |
| Total no. of cases | 2 | 25 | 12 | 13 | 2 | 1 | 2 | 1 | 2 |
| Result | | | | | | | | | |
| Excellent | 2 | 16 | 3 | 7 | 0 | 1 | 1 | 0 | 1 |
| Good | 0 | 2 | 3 | 2 | 0 | 0 | 1 | 0 | 0 |
| Fair | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Poor | 0 | 2 | 3 | 1 | 2 | 0 | 0 | 0 | 0 |
| Unknown | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Died | 0 | 5 | 3 | 1 | 0 | 0 | 1 | 1 | 1 |
| Coxa vara | 0 | 2 | 3 | 2 | 0 | 0 | 0 | 0 | 0 |
| Medial migration | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 |
| Nail bend | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nail break | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| Nail protrusion | 0 | 1 | 2 | 2 | 2 | 0 | 0 | 0 | 0 |
| Non-union | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| Aseptic necrosis | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

2. This patient was lost to follow-up after eight months. Five and one-half years later he was found with non-union as shown in Figures 5-A, 5-B, and 5-C.

3. This patient's last roentgenogram and visit to the Clinic were made seven months after the fracture. According to his family he had to use one crutch until his death three years later (Figs. 4-A through 4-D).

4. This was a case of Type III-A fracture in a fifty-seven-year-old male treated by Neufeld nailing. When last examined, three years later, he was walking with the aid of a cane.

5. Neufeld-nail fixation of a Type IV fracture in a thirty-four-year-old male resulted in medial migration of the distal fragment with coxa vara, protrusion of the nail, two inches of shortening, and non-union. Secondary surgery was performed by the author three years after the first operation. Loose fibrous union was found at the fracture site. The nail was removed. A subtrochanteric osteotomy with Key nailing and bone-grafting was performed. Bone length was restored and the functional and anatomical results were excellent.

6. Neufeld-nail and spica-cast fixation of a Type VI-C fracture in a fifty-one-year-old male resulted in coxa vara and non-union, which was confirmed when secondary surgery, a subtrochanteric osteotomy and bone-grafting, was performed twenty months later. Roentgenograms made six months after the second operation showed smooth sclerotic bone edges at the fracture site and a prominent fracture line.

## COMPLICATIONS

Complications occurred in thirty-one of thirty-nine patients (79.5 per cent) treated non-operatively and in twenty-one of fifty-nine patients (35.6 per cent) operated upon. The result in one patient with operation is unknown. Large infected decubitus ulcers, hypostatic pneumonia, and urinary complications were the more frequent non-operative complications. There were two cases of superficial wound infection (without clinical evidence of bone infection). It is interesting to note that three cases of thrombophlebitis, one case of massive fatal pulmonary embolism, and one extensive femoral-vein thrombosis, all occurred in the operative group.

In one patient, protrusion of the nail occurred two months postoperatively; the nail

TABLE IV

RESULTS

| Results | Operative 60 Cases (*No. of Cases*) | (*Per cent*) | Non-operative 39 Cases (*No. of Cases*) | (*Per cent*) |
|---|---|---|---|---|
| Excellent | 31 | 51.6 | 5 | 12.8 |
| Good | 8 | 13.3 | 8 | 20.5 |
| Fair | 1 | 1.7 | 1 | 2.5 |
| Poor | 7 | 11.6 | 5 | 12.8 |
| Died | 12 | 20.0 | 20 | 51.2 |
| Unknown | 1 | 1.6 | 0 | |

*Excellent:* No impairment of function, no shortening. *Good:* No impairment of function, one-half inch or less of shortening. *Fair:* Slight impairment of function, one-half to one inch of shortening. *Poor:* Moderate or severe impairment of function, shortening of more than one inch, or both. *Unknown:* End results not known.

was removed and a shorter nail was inserted with excellent results. Several patients refused to allow removal of the nail even though it had protruded or broken. Avascular necrosis of the femoral head developed in one patient; in another, there was destruction of the upper half of the acetabulum and femoral head; and complete resorption of the bone adjacent to the nail occurred in a third patient.

## MORTALITY RATE

The mortality rate is based upon the total number of deaths occurring in the Hospital, and no case or group of cases has been excluded (Table II). Seven patients entered the Hospital in a terminal state after considerable delay; two refused to leave and died in the Hospital several months after they would have been discharged. Even if these patients were excluded, the non-operative mortality rate would still be 36.6 per cent of patients, nearly double that of the operative group.

## NON-UNION

Non-union is generally accepted as rare in trochanteric fractures of the femur [1,3,5,7]. Key states that trochanteric fractures tend to unite no matter how they are treated. Stuck reported that he had never seen or heard of a case of non-union in trochanteric fractures of the femur. However, in this series, there were six cases of non-union which have been discussed.

## RESULTS

The final outcome is known in ninety-eight of the ninety-nine cases, (98.98 per cent). The results were rated functionally according to whether the patient was able to return to his pre-fracture state of activity, and anatomically according to the degree of restoration of the normal neck-shaft angle, bony union, position, and length of the extremity (Tables III and IV).

Coxa vara deformity, medial migration of the distal fragment, shortening, and non-union were the major causes of poor results among the surviving patients treated non-operatively. Gradual protrusion of the nail through the femoral head (overdrive) and non-union were the main causes of poor results in the patients treated by internal fixation.

## SUMMARY

This presentation of ninety-nine cases of trochanteric fractures of the femur in the Negro with a 6 per cent incidence of non-union indicates that this type of fracture does occur in the Negro and that it may not unite.

The age and sex incidence, high frequency of trivial injury, numerous concomitant disorders, high mortality rate of patients treated non-operatively, complications, and the long delay in hospitalization are striking.

These elderly poor-risk patients were found to tolerate anaesthesia and surgery very well. The oldest patient operated upon in this series was 101 years old. By the almost routine use of internal fixation in the old-age group, especially in debilitated poor-risk patients, we have been able to:

1. Reduce the hospital-case mortality rate from 50 per cent to less than 20 per cent.
2. Reduce the incidence of such complications as decubitus ulcers, hypostatic pneumonia, urinary disorders, thrombophlebitis, and pulmonary embolism from an incidence of 79.5 per cent in cases without operation to 35.6 per cent.
3. Increase the over-all good results from 33 per cent to 64.7 per cent.
4. Discharge these old people in a matter of days instead of months.

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# Acute Suppurative Arthritis

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Despite the widespread use of antibiotics in the prevention and control of local and general infection, the incidence of acute suppurative arthritis at the New York Orthopaedic Hospital has not changed significantly over the past twenty years. Inge and Liebolt reported thirty-six cases of surgically treated suppurative arthritis at this Hospital over a fifteen-year period, prior to the antibiotic era (1918 to 1933). In twenty-two of these cases the disease was bacteriologically proved and was uncomplicated by bone infection at the time of operation. During the period 1934 to 1955, fifty-one patients with acute joint

TABLE I

INCIDENCE

| Age | Male | Female | Total |
|---|---|---|---|
| 0–1 year | 5 | 8 | 13 |
| 1–6 years | 3 | 6 | 9 |
| 7–16 years | 7 | 0 | 7 |
| 17–40 years | 7 | 2 | 9 |
| Over 40 years | 8 | 5 | 13 |
| | 30 | 21 | 51 |

TABLE II

JOINTS INVOLVED

| Joint | No. of Joints | Age in Years 0–1 | 1–6 | 7–16 | 17–40 | Over 40 |
|---|---|---|---|---|---|---|
| Hip | 18 | 7 | 2 | 4 | 2 | 3 |
| Knee | 19 | 3 | 3 | 2 | 5 | 6 |
| Ankle | 3 | 0 | 2 | 0 | 0 | 1 |
| Sacro-iliac | 1 | 0 | 0 | 0 | 0 | 1 |
| Shoulder | 2 | 1 | 1 | 0 | 0 | 0 |
| Elbow | 9 | 4 | 1 | 1 | 1 | 2 |
| Small joints of hand | 3 | 0 | 0 | 1 | 1 | 1 |
| Multiple joints | 3 | 1 | 0 | 0 | 1 | 1 |
| Totals | 58 | 16 | 9 | 8 | 10 | 15 |

infection, bacteriologically proved by joint aspiration and uncomplicated by osteomyelitis when first diagnosed, were admitted to the New York Orthopaedic Hospital and allied services at the Columbia-Presbyterian Medical Center. An analysis of this series and of the earlier series from the same institution provided a comparative study of the results of treatment by aspiration and specific antibiotics and by incision and drainage. Cases of gonococcal arthritis were excluded because this condition, both pathologically and clinically, constitutes a separate disease entity.

A statistical analysis of the fifty-one cases seen since 1934 reveals that there were thirty males and twenty-one females, with an age variation of from a few weeks to seventy-one years (Table I). Thirteen patients were under one year of age and nine were one to six years of age. Thus 43 per cent of the acute suppurative joints were found in children under seven years of age.

In this series, the knee joint was involved in nineteen cases (37 per cent) and the hip joint in eighteen cases (35 per cent) (Table II). Heberling reported a similar incidence of involvement of the knee (36 per cent) and hip (32 per cent) in 201 cases. Inge and Liebolt found a higher incidence of hip infection (46 per cent) than of knee infection (27 per cent).

## ETIOLOGY

Of the organisms isolated from the aspirated joint fluid, *Staphylococcus aureus* was found in 35 per cent of the cases and Streptococcus in 24 per cent (Table III).

The organisms were introduced into the joint by direct puncture in seven cases. Four cases resulted from children kneeling on sewing needles. Hematogenous spread from a distant focus of infection was thought to be the cause of the joint suppuration in forty-four cases. In nineteen patients a definite pre-existing infection was demonstrated. In children this usually was an upper respiratory infection. In several adults acute suppurative arthritis developed shortly following cystoscopy.

TABLE III

ORGANISMS

| Organism | No. of Cases | Age in Years 0–1 | 1–6 | 7–16 | 17–40 | Over 40 |
|---|---|---|---|---|---|---|
| Staphylococcus aureus | 18 | 4 | 1 | 4 | 3 | 6 |
| Other Staphylococcus | 3 | 0 | 1 | 1 | 1 | 0 |
| Pneumococcus | 7 | 4 | 0 | 0 | 1 | 2 |
| Bacillus typhosus | 1 | 0 | 1 | 0 | 0 | 0 |
| Streptococcus | 12 | 3 | 3 | 1 | 2 | 3 |
| Bacillus influenzae | 3 | 2 | 1 | 0 | 0 | 0 |
| Multiple organisms | 7 | 0 | 2 | 1 | 2 | 2 |
| Totals | 51 | 13 | 9 | 7 | 9 | 13 |

## DIAGNOSIS

The diagnosis of acute suppurative arthritis in the early phase of the disease often is difficult. The usual clinical signs of marked muscle spasm with restriction of motion, increased local temperature, and severe systemic reaction may be masked by the use of non-specific antibiotics prior to diagnostic aspiration. The roentgenographic examination may be of little help in the early stages of the disease, although occasionally the presence of capsular distention may be revealed by the soft-tissue shadows. The laboratory finding of leukocytosis with a shift toward the immature types and the presence of an elevated erythrocyte sedimentation rate are of considerable significance. In every case in this series the diagnosis was established by joint aspiration and the demonstration of pathogenic organisms in the smears and cultures obtained from the aspirated material.

At this Hospital acute non-specific synovitis has been the condition which has most frequently simulated the early clinical signs of acute suppurative arthritis, particularly in the hip. This type of joint involvement is fairly common in young children, the age group with the highest incidence of acutely infected joints. A low leukocyte count and little or no elevation of the erythrocyte sedimentation rate, together with a minimal

systemic reaction, are findings suggestive of the diagnosis of synovitis. Joint tuberculosis and monarticular rheumatoid arthritis are other conditions which not infrequently present problems in the differential diagnosis. Aspiration of the joint has been the most reliable diagnostic aid in doubtful cases. The consequences of delay in the diagnosis of an acutely infected joint may be disastrous, and in doubtful cases it behooves the clinician to eliminate a diagnosis of acute suppurative arthritis before considering a diagnosis of non-specific inflammatory reaction.

## TREATMENT

It has long been the practice at the New York Orthopaedic Hospital to incise and drain an acutely infected joint as soon as feasible after the diagnosis has been established. If there is strong clinical and laboratory evidence of joint suppuration, this procedure is undertaken without waiting for bacteriological proof of the diagnosis. The authors believe

TABLE IV

PATIENTS TREATED BY ARTHROTOMY AND DRAINAGE

| No. of Days Symptoms Appeared Prior to Arthrotomy | No. of Patients | Preoperative Antibiotic Treatment | Age in Years 0–1 | 1–6 | 7–16 | 17–40 | Over 40 |
|---|---|---|---|---|---|---|---|
| 0–2 | 5 | 1 | 0 | 2 | 2 | 1 | 0 |
| 3–4 | 3 | 2 | 1 | 1 | 0 | 1 | 0 |
| 5–7 | 4 | 2 | 1 | 1 | 0 | 0 | 2 |
| Over 7 | 25 | 12 | 5 | 4 | 5 | 5 | 6 |
| Totals | 37 | 17 | 7 | 8 | 7 | 7 | 8 |

TABLE V

PATIENTS TREATED BY ASPIRATION AND SPECIFIC ANTIBIOTICS

| No. of Days Symptoms Appeared Prior to Aspiration | No. of Patients | Age in Years 0–1 | 1–6 | 7–16 | 17–40 | Over 40 |
|---|---|---|---|---|---|---|
| 0–2 | 2 | 2 | 0 | 0 | 0 | 0 |
| 3–4 | 1 | 1 | 0 | 0 | 0 | 0 |
| 5–7 | 3 | 1 | 0 | 0 | 1 | 1 |
| Over 7 | 8 | 2 | 1 | 0 | 1 | 4 |
| Totals | 14 | 6 | 1 | 0 | 2 | 5 |

that the harmful results of failure to drain an infected joint far outweigh the risk involved in opening a normal one. Since the introduction of antibiotics, these drugs have been used in conjunction with surgery. Usually one or two of the broad-spectrum antibiotics are given systemically until sensitivity tests of the cultured exudate have been completed.

In this series, thirty-seven patients were treated by incision and drainage following diagnostic aspiration (Table IV).

The treatment of acute suppurative arthritis by aspiration and instillation of a specific antibiotic into the joint has gained favor in some clinics during the past few years. Altemeier and Largen reported seventy cases of acute suppurative arthritis in which the joint was drained surgically only when antibiotic therapy failed or when there was mixed infection. In the authors' series fourteen patients were treated by aspiration and the instillation of specific antibiotics (Table V).

COMPLICATIONS

The number and type of complications encountered had a direct relationship to the duration of symptoms prior to diagnosis and definitive treatment (Table VI). A striking finding is the fact that 85 per cent of all complications (excluding death from septicaemia) occurred in those patients who had had symptoms for seven or more days prior to diagnosis and specific treatment. The incidence of complications, except for pathological dislocation of the hip, was about the same whether the patient was treated by specific antibiotics or by incision and drainage following diagnostic aspiration. There were eight deaths due to septicaemia.

TABLE VI

COMPLICATIONS

| Complication | No. of Cases | No. of Days Symptoms Appeared Prior to Specific Therapy | | | | Aspiration and Antibiotics | Arthrotomy |
|---|---|---|---|---|---|---|---|
| | | 0–2 | 3–4 | 5–7 | Over 7 | | |
| Pathological dislocation of hip | 8 of 18 hips | 0 | 1 | 0 | 7 | 3 (of 5 cases) | 5 (of 13 cases) |
| Coxa plana | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| Subsequent osteomyelitis | 20 | 1 | 1 | 2 | 16 | 5 (of 14 cases) | 15 (of 37 cases) |
| Spontaneous ankylosis | 4 | 0 | 0 | 0 | 4 | 2 | 2 |
| Death (septicaemia) | 8 | 0 | 0 | 1 | 7 | 3 | 5 |

TABLE VII

CRITERIA FOR END-RESULT RATINGS

| Rating | Anatomy (X-Ray Examination) | Symptoms | Function |
|---|---|---|---|
| 1 | Marked joint destruction with or without pathological dislocation or ankylosis | Pain on minimal motion | Marked limitation of joint motion with limp, shortening, or both |
| 2 | Moderate destruction of joint surfaces without pathological dislocation or ankylosis | Pain on functional use | Moderate limitation of motion, limp, moderate disability |
| 3 | Minimal joint destruction with mild resultant osteo-arthritis | Pain on vigorous use, bad-weather ache | Minimal limitation of motion, no limp, minimal disability |
| 4 | Normal joint | Asymptomatic | No disability |

Pathological dislocation of the hip occurred in eight of the eighteen patients with hip-joint infection. Three of these dislocations occurred in the group of five patients treated by antibiotics and aspiration and five occurred in the group of thirteen patients treated by arthrotomy. Seven of the eight pathological dislocations were noted in patients who had had symptoms seven days or more before the diagnosis of acute suppurative arthritis was made. *Staphylococcus aureus* was the offending organism in six of the eight cases.

Osteomyelitis subsequently developed in contiguous bones in twenty patients (39 per

cent). Sixteen of these patients had symptoms seven or more days prior to diagnosis and definitive treatment. Heberling reported an incidence of 12 per cent in his series of patients treated during the pre-antibiotic era.

Spontaneous ankylosis occurred in four patients, and coxa plana was noted in one.

## RESULTS

The results of treatment in this series of cases were rated on the basis of anatomy, symptoms, and function (Tables VII and VIII). A rating of *4–4–4* designated an excellent

TABLE VIII

END RESULTS

| Appearance of Symptoms Prior to Aspiration or Arthrotomy *(Days)* | No. of Deaths | Follow-up Less than 2 Years | Results Anatomy 4 3 2 1 | Symptoms 4 3 2 1 | Function 4 3 2 1 |
|---|---|---|---|---|---|
| 0–2 (2 cases of aspiration) | 0 | 1 | 0 0 0 1 | 0 0 1 0 | 0 1 0 0 |
| (5 cases of arthrotomy) | 0 | 1 | 4 0 0 0 | 4 0 0 0 | 4 0 0 0 |
| 3–4 (1 case of aspiration) | 0 | 0 | 1 0 0 0 | 1 0 0 0 | 1 0 0 0 |
| (3 cases of arthrotomy) | 0 | 1 | 0 2 0 0 | 1 1 0 0 | 1 1 0 0 |
| 5–7 (3 cases of aspiration) | 0 | 0 | 1 1 0 1 | 1 1 0 1 | 2 0 0 1 |
| (4 cases of arthrotomy) | 1 | 1 | 0 1 0 1 | 1 0 0 1 | 1 0 0 1 |
| Over 7 (8 cases of aspiration) | 3 | 2 | 1 1 0 1 | 3 0 0 0 | 2 1 0 0 |
| (25 cases of arthrotomy) | 4 | 3 | 4 3 5 6 | 7 3 5 3 | 4 3 5 6 |
| Total (14 cases of) aspiration) | 3 | 3 | 3 2 0 3 | 5 1 1 1 | 5 2 0 1 |
| (37 cases of) arthrotomy) | 5 | 6 | 8 6 5 7 | 13 4 5 4 | 10 4 5 7 |

result, a rating of *3–3–3* or better a good result. A fair result was given a rating of *2–2–2* or better, and a rating of *1* was included if the result was poor. Patients with less than a two-year follow-up (nine cases) were excluded from the end-result analysis. The average period of follow-up was slightly under five and one-half years (Table IX).

In order to simplify the tabulation of the results and in order to compare the results with those obtained in the cases reported by other authors (Table X), the cases in this series were grouped in categories of excellent, good, fair, and poor. In this comparative study, only twenty-two of the thirty-six cases reported by Inge and Liebolt were used, the ten cases in which osteomyelitis developed and the four cases in which bacteriological proof was not obtained being excluded. The criteria used to classify the results in these cases as excellent and good and as fair and poor corresponded to the criteria used by

Heberling to classify the results in his cases as satisfactory and unsatisfactory, respectively. In his report Heberling analyzed the final results in only 143 of the 201 cases presented.

Because 43 per cent of the patients in the present series were children under seven years of age, the term "interim results" is a more accurate description of the final evaluation than the term "end results".

The results in the authors' series were very similar to those obtained by Heberling in his series of patients treated during the pre-antibiotic era. Two-thirds of his results were satisfactory, while one-third were unsatisfactory.

The series reported by Altemeier and Largen is not comparable with the present series, because gonococcal arthritis represented fully one-third of their cases. Furthermore, follow-up was maintained for only three and one-half years; and lastly, it is not clear from their report how many patients were eventually treated by incision and drainage.

## DISCUSSION

In selecting the material for this study, cases in which roentgenographic evidence of osteomyelitis was revealed within three weeks of the onset of symptoms were excluded. The authors believe that joint infections resulting from, or occurring simultaneously with,

TABLE IX

FOLLOW-UP

| Length of Follow-Up (*Years*) | No. of Cases |
|---|---|
| Less than 2 | 9 |
| 2–4 | 12 |
| 5–10 | 11 |
| 10–15 | 7 |
| Over 15 | 4 |
| Deaths | 8 |
| Average Follow-Up: 5.4 Years | 51 |

osteomyelitis of the adjacent bones should be classified separately. In such cases the prognosis for a good functioning joint is much less favorable than it is in cases of uncomplicated pyarthrosis; furthermore, because of the osteomyelitis, special problems in management may be present from the beginning.

Inasmuch as the emphasis in this report has been on early diagnosis and treatment of acute suppurative arthritis, cases in which osteomyelitis developed later as a complication were included.

Inge and Liebolt classified separately twenty-two cases of suppurative arthritis uncomplicated by bone infection and ten cases in which osteomyelitis was present at the joint. In the latter group, the hip was the joint affected in every case, and osteomyelitis of the femur or acetabulum or of both was present at the time of admission to the hospital. In discussing the operative findings in the group of cases in which there were no complications, the authors stated: "In no case . . . was there any destruction of bone, either before the arthrotomy, or subsequent to it. Nor was there any case of phlegmon extending from the joint through the fascial planes of the extremity."

In evaluating the cases in the present series and in reviewing the studies of suppurative arthritis reported by others, the authors were impressed by the uniformity of the over-all results. Because of the recent introduction of antibiotics, the results in the present series should be comparatively better than those in the earlier series. However, anti-

biotics cannot be relied upon to control the disease in an infected joint unless evacuation of the purulent material is obtained, either by aspiration or open drainage. The symptoms and clinical findings may be masked by use of non-specific antibiotics in the early stages of the disease, thereby leading to delay in diagnosis and definitive treatment. In this study, delay in diagnosis was associated with the use of non-specific antibiotic therapy before diagnostic aspiration in 42 per cent of the cases. Increased bacterial resistance resulting from systemic antibiotic therapy may be a factor in confusing the diagnosis and may be responsible for subsequent complications.

The results in this series were consistently related to the time interval between the onset of symptoms and the diagnosis and specific treatment. There were only seven cases diagnosed within the first two days after the onset of symptoms. In five of these the patient was treated by incision and drainage with excellent results. One of the two patients

TABLE X

COMPARATIVE-RESULT STUDY

| Year | No. of Cases | Study | Deaths (*Per cent*) | Follow-Up Less Than 2 Years (*Per cent*) | Results: Excellent (*Per cent*) | Good (*Per cent*) | Fair (*Per cent*) | Poor (*Per cent*) |
|---|---|---|---|---|---|---|---|---|
| 1955 | | Authors: | | | | | | |
| | 14 | Aspiration | 21 | 21 | 54 | 21 | 4 | 20 |
| | 37 | Arthrotomy | 14 | 16 | 40 | 18 | 18 | 23 |
| 1935 | 22 | Inge and Liebolt * | 0 | | 54 | 23 | 4 | 9 |
| | | | | | Satisfactory | | Unsatisfactory | |
| 1941 | 143 | Heberling | 18 | | 68 | | 32 | |

* Two cases in this series (10 per cent) could not be classified because of insufficient data.

treated by aspiration and instillation of antibiotics had a poor result. The three patients treated by incision and drainage within four days of onset of symptoms had good or excellent results. When treatment was delayed over five days, the result seemed to be comparable regardless of the method of joint evacuation, with one exception. Pathological dislocation of the hip appeared to occur with greater frequency in the patients treated by aspiration than in those treated by incision and drainage. (This finding cannot be considered conclusive, as this series was too small for the results to be statistically significant.) Perhaps the hip joint cannot be evacuated adequately by repeated aspirations, with the result that there is prolonged intra-articular pressure and subsequent pathological dislocation.

Although the number of cases which were diagnosed early is too small for conclusive evaluation, the uniform excellence of the results following incision and drainage favors this treatment as the more certain method of preventing permanent damage to the joint. The greater frequency of pathological dislocations in hips treated by aspiration and the instillation of antibiotics supports this conclusion.

## CONCLUSIONS

1. Acute suppurative arthritis should be treated on an emergency basis, and the diagnosis should be established by joint aspiration or exploratory arthrotomy if necessary.

2. Antibiotics should be withheld until aspiration has been performed.

3. Early diagnosis is the key to successful results.

4. Open drainage of an infected joint is the treatment of choice, particularly in pyarthrosis of the hip.

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# Thyroid Function in Legg-Perthes Disease

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In common with the other osteochondroses, Legg-Perthes disease is still considered by most authorities to be of unknown etiology. The degeneration of the capital femoral epiphysis, which characterizes this disease, is generally thought to be an aseptic necrosis secondary to an inadequate blood supply. Many orthopaedic surgeons believe that trauma is the initiating factor, but this has never been proved. The idea is widely held that hormonal imbalance, particularly hypothyroidism, might be the underlying cause, although this is often disputed. The theory was advanced in 1936 by Cavanaugh, Shelton, and Sutherland on the basis of five patients who showed some of the symptoms associated with hypothyroidism, and who were thought to have benefited from thyroid medication. In 1943, on the basis of the published evidence, Gill questioned whether these patients had in fact been helped by the thyroid medication. He similarly questioned the conclusions of Schaefer and Purcell, who had treated two patients with Legg-Perthes disease with desiccated thyroid. The latter authors held that not only Legg-Perthes disease, but all the juvenile osteochondroses were due to hypothyroidism. However, Gill could find no evidence of hypothyroidism in a careful study of twenty cases of Legg-Perthes disease.

The accuracy of the measurement of thyroid function has been greatly improved by the introduction of the chemical determination of the serum protein-bound iodine and by the various tests utilizing radioactive iodine. Emerick and his group, by the use of thyroid radioactive iodine uptake studies (including mapping of the activity in the thyroid gland by means of a well collimated counter), found that all of their last thirty-five patients with Legg-Perthes disease had either hypothyroidism or toxic adenomata. More recently, Katz, using serum protein-bound-iodine determinations and serum cholesterol levels, could find no evidence of abnormal thyroid function in thirty-two patients with Legg-Perthes disease.

In view of the contradictory reports in the literature we felt that a study of our cases of Legg-Perthes disease would be of value. Ten current cases from the Orthopaedic Clinic were chosen for the study, six males and four females, ranging in age from four years to fourteen years. All had unilateral Legg-Perthes disease. The children were studied by means of serum protein-bound-iodine determinations, twenty-four-hour thyroid radioactive iodine uptakes (including mapping of the localization of radioactivity within the thyroid gland), and, in seven cases, determination of the radioactive-iodine concentration in the saliva. None of these children showed any clinical evidence of thyroid dysfunction. The results of these studies are shown in Table I. It will be noted that half of these patients were in the degenerating phase of the disease and half were in the regenerating phase. The known duration of the disease ranged from six weeks to twenty-five months.

The radioactive-iodine uptake was measured with a scintillation counter, with a 1.5 millimeter lead filter, at a distance of 30 centimeters, twenty-four hours after the oral administration of the tracer dose. A collimator with a one-centimeter opening was also used at short range to determine the activity of various portions of the thyroid gland.

TABLE I

| Patient | Age | Sex | Duration | Asymmetrical Uptake | Stage | Saliva Iodine | Protein-bound Iodine* | 24-hour Iodine (Per cent) |
|---|---|---|---|---|---|---|---|---|
| E. W. | 6 | F | 21 mos. | O | Regeneration | Normal | 6.4 | 37 |
| R. D. | 14 | M | 21 mos. | O | Regeneration | Normal | 4.3 | 33 |
| W. P. | 6 | M | 9 mos. | O | Degeneration | Normal | 5.9 | 28 |
| R. W. | 9 | M | 25 mos. | O | Degeneration | | 4.9 | 38 |
| G. H. | 4 | M | 22 mos. | L>R | Degeneration | | 4.5 | 28 |
| G. S. | 4 | M | 12 mos. | O | Degeneration | Normal | 7.7 | 26 |
| | | | | | | | 4.6 | |
| M. M. | 7 | F | 6 wks. | R>L | Regeneration | Normal | 7.2 | 33 |
| | | | | | | | 5.8 | |
| S. L. | 7 | F | 14 mos. | O | Regeneration | Normal | 5.8 | 35 |
| J. B. | 6 | F | 25 mos. | O | Regeneration | Normal | 8.5 | 35 |
| | | | | | | | 3.6 | |
| C. W. | 13 | M | 4 mos. | 0 | Degeneration | | 5.7 | 28 |

* Micrograms per 100 cubic centimeters of serum.

In all patients the uptake of radioactive iodine was well within our normal range of 20 to 45 per cent, ranging only from 26 to 38 per cent. Only two patients (G. H. and M. M.) showed any evidence of localization of activity within the thyroid gland when counts were made with the small collimator. In these two cases one lobe of the thyroid gland had approximately twice the activity of the other lobe, but no closer localization of the activity could be made. One of these patients (M. M.) also had a slightly high level of protein-bound iodine (7.2 micrograms per 100 cubic centimeters of serum), but a subsequent determination of the protein-bound iodine was 5.7, well within the normal limits (3.5 to 7.0 micrograms per 100 cubic centimeters of serum) for our laboratory.

Seven of the ten patients with Legg-Perthes disease had levels of protein-bound iodine well within normal limits, one had a borderline level (7.2), and two had levels definitely elevated (7.7 and 8.5). The reason for the elevated protein-bound-iodine determinations in these three cases was never determined. No pertinent history of drug therapy could be obtained. After an interval of five months during which no drug therapy was given, a second protein-bound-iodine determination showed normal results in all three cases.

It has recently been shown by Thade, Jaimet, and Kirkwood that the radioactive-

iodine concentration in the saliva twenty-four hours after a tracer dose is high in hypothyroidism and low in hyperthyroidism. We have found this to be true, although we have not found a sharp margin between the levels in patients with thyroid disease and the upper and lower extremes in the normal patients. We measured the radioactivity of a saliva sample taken twenty-four hours after the tracer dose in seven of the patients. All the saliva counts were within our established normal range. Only one of the patients (S. L.) had a saliva count close to the hyperthyroid range and her other studies were all normal.

SUMMARY

The thyroid function of ten patients with Legg-Perthes disease was studied by means of clinical examination, chemical serum protein-bound-iodine determination, and twenty-four-hour thyroid uptakes. Salivary radioactive iodine concentration was also measured in seven of the ten patients.

Three patients had slightly elevated serum protein-bound-iodine levels, but the other tests and subsequent normal protein-bound-iodine determinations satisfactorily ruled out hyperthyroidism.

Two patients showed definite asymmetry of radioactive-iodine uptake in the thyroid gland. We cannot rule out the possibility of hyperfunctioning adenoma in these patients, but over-all thyroid function was normal.

There was no evidence of hypothyroidism in any of the patients.

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# Primary Vitamin-D Resistant Rickets

## III. Biophysical Studies of Skeletal Tissue

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In recent years there has been considerable interest in primary vitamin-D resistant rickets, and a great number of cases have been reported in pediatric and orthopaedic literature [13, 15]. There is evidence that the disease is genetically determined [10] but its pathogenesis remains obscure.

The purpose of the investigation reported in this paper was to discover characteristics in the skeletal tissue of patients with primary vitamin-D resistant rickets which would indicate the pathogenesis of the disease.

Bone biopsy specimens were obtained from four patients with primary vitamin-D resistant rickets. The mineral distribution in different areas of bone, the organization of the collagen bundles, and the ultrastructure were studied by various biophysical methods as well as ordinary histological means.

### MATERIAL

The clinical course of each of the four cases studied is reported:

Case 1: A six-year-old boy was admitted to the hospital with symptoms of severe vitamin-D resistant rickets. The family history was irrelevant. Roentgenographic examination of the skeleton was made. Massive doses of vitamin D were administered, resulting in a decrease of the serum alkaline phosphatase activity and normalization of the skeletal mineral content. Before vitamin-D therapy was begun, the costochondral junction from one of the patient's ribs was removed for laboratory study [15].

Case 2: A three-year-old boy was admitted to the hospital with symptoms and clinical findings typical of vitamin-D resistant rickets. The family history was irrelevent. Treatment with massive doses of vitamin D resulted in immediate and sustained improvement. The costochondral junction from one of the patient's ribs was removed for study before therapy was begun [15].

Case 3: A three-year-old girl was admitted whose father and two uncles had bowed legs. Clinical and roentgenographic examination revealed characteristic indications of vitamin-D resistant rickets. Figure 1-A is a roentgenogram of the patient's right knee. In addition to the typically rachitic changes in the bone, an abnormal texture of the diaphysis can be seen as well as the absence of normal compact bone. A roentgenogram of the patient's left wrist is shown in Figure 1-B. Characteristics and findings are the same as in Figure 1-A. The serum phosphorus level varied between 2.5 and 3.0 milligrams per 100 milliliters, and the serum calcium level varied between 10.2 and 10.8 milligrams per 100 milliliters. Serum alkaline phosphatase activity was 30 to 40 units [4] per 100 milliliters. Treatment with massive doses of vitamin D was begun, but after two months symptoms developed of vitamin-D intoxication and the treatment was discontinued for several months. When therapy was resumed, the dosage was kept relatively low.

Bilateral tibial osteotomy was performed one year after the start of therapy. At the time of surgery, the serum phosphorus level was 4.0 milligrams per 100 milliliters, the serum calcium level was 10.0 milligrams per 100 milliliters, and serum alkaline phosphatase activity was 20 units per 100 milliliters. Roentgenograms made at the time of surgery showed a notable increase of mineralization when compared to those made a year earlier and the growth-zone was almost normal. However, the appearance of the skeleton still indicated an active rachitic process, and the abnormal structure of the diaphysis was not corrected (Fig. 1-C). Compact bone, obtained at the osteotomy, was studied. Because of the intensive vitamin-D treatment given the patient prior to surgery it had been anticipated that study of this specimen would yield us much information about the structure and mineralization of the skeleton after increased deposits of mineral salts.

Case 4: A girl, three years old, was admitted with severe primary vitamin-D resistant rickets. She had multiple deformities and was unable to walk without support. Her parents and six siblings showed no signs of rachitic deformities. A cousin was said to have severe rickets. The patient's serum phosphorus level varied between 1.5 and 2.5 milligrams per 100 milliliters; the serum calcium level was 10.5 milligrams per

FIG. 1-A

100 milliliters, and the serum alkaline phosphatase activity was about 150 units per 100 milliliters. Massive doses of vitamin D were given, and after three months of treatment, roentgenograms showed increased calcification of the skeleton. Before vitamin-D therapy was begun, a piece of the bony part of one rib was removed from the patient for study.

## METHODS

Thin longitudinal and transverse slices were cut from bone by means of a rotating saw with a thin blade. Some of these specimens were embedded in methyl-methacrylate and ground down on glass plates to a thickness of about 100 micra. The distribution of mineral salts in these sections was studied by microradiography, soft x-rays being used. In general the technique described by Engström and Wegstedt was used. X-rays were generated at ten kilovolts and were filtered through 0.2 millimeter beryllium. The microradiograms were registered on Kodak spectroscopic plates and were secondarily enlarged by photomicrography. With the procedure used, the resolving power was better than one micron. After microradiography, the sections were decalcified in a neutral solution of the disodium

FIG. 1-B

FIG. 1-C

Fig. 1-A: Case 3. Roentgenogram made on admission. There are rachitic changes in the growth zones and abnormal structure of the diaphyseal bone.

Fig. 1-B: Roentgenogram of the left wrist made on admission. Typical rachitic changes are shown in the growth zones.

Fig. 1-C: Roentgenogram made of the same wrist after treatment with massive doses of vitamin D. There is increased density, especially in the growth zones, but the structure is still abnormal.

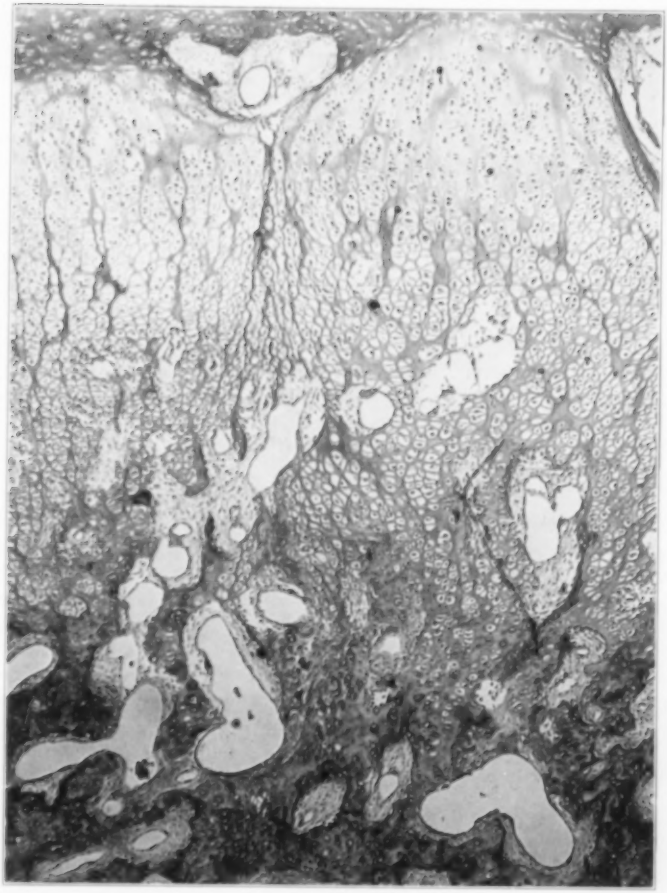

FIG. 2

Photomicrograph of ten-micra section through the costochondral junction showing the broad irregular zone of proliferating cartilage (hematoxylin and eosin, × 90).

salt of ethylenediamine tetra acetic acid and were mounted for study, in polarized light, of the organization of the collagen fibers. For morphological studies, decalcified specimens were embedded in paraffin and were treated according to routine histological methods.

With the aid of the microradiograms, areas of varying degrees of mineralization were selected for micro-x-ray diffraction studies, a Chesley microdiffraction camera adapted to a Philips diffraction unit being used.

## RESULTS

### *Histological Examination*

Histological examination of biopsy material obtained from the rib-growth zone in Cases 1 and 2 showed marked deviations from the normal. The zones of proliferating cartilage of the costochondral junction had greatly expanded and appeared irregular (Fig. 2). Wide, thin-walled blood vessels were seen running from the marrow cavity through the

proliferating cartilage, dividing it into irregular lobules. Osteoid tissue was present in large amounts. These changes resembled those that take place in ordinary advanced rickets. Transverse sections of rib-bone tissue varied in appearance. The tissue, seen microscopically, was never altogether normal, although occasionally an outer circumferential lamella and compact bone with a few normal appearing Haversian systems were seen. In many areas, however, irregular bone trabeculae replaced the outer lamella and the compact bone. Small amounts of osteoid were present in these areas and a great number of resorption cavities were observed.

Microscopically, transverse sections of bone from a portion of the tibia in Case 3 showed broad trabeculae separated by wide areas of bone marrow. The trabeculae often had a mosaic-like structure, and osteoid tissue was scanty. Osteoblastic borders and resorption cavities were frequently seen. In a few instances, osteoclasts were observed. The occurrence of osteocytes in the bone trabeculae appeared to be normal.

A section from a portion of the tibia of a patient who had been treated with large doses of vitamin D showed a mosaic-like pattern in the bone which was not consistent with rickets. The structure resembled formations seen in Paget's disease. Such changes were also observed in a pre-treatment biopsy of the bony part of a patient's rib.

*The Distribution of Mineral Salts as Seen in the Microradiograms*

The normal pattern of transverse sections of rib bone is shown in Figure 3-A. An outer circumferential lamella surrounds compact bone with typical Haversian systems. An irregular pattern appeared in all microradiograms of the skeletal tissue taken from patients with vitamin-D resistant rickets (Figs. 4-A, 4-B, 5-A, 6-A, 6-B, 7-A, and 7-B). In cross sections of the rib specimens, the trabeculae showed widely varying areas of mineralization. Occasionally there was accentuation of the fine lamellar structure of bone [8] which could also be observed in the longitudinal sections. Varying mineralization was also found in sections from the tibia; some showed highly mineralized trabecular areas. A pronounced mosaic pattern was often observed. In some areas, corresponding to the outer part of the bone tissue, Haversian systems were formed. These systems had wide marrow cavities and lacked uniformity; there were areas of bone destruction and broad zones of poorly mineralized tissue. In these areas, osteocyte spaces were often wide and irregular, and poorly defined. Similar changes were also seen in the highly mineralized portions of the trabeculae (Fig. 6-B).

*Decalcified Transverse Sections Studied in Polarized Light*

The collagen pattern of these sections appeared unusually irregular and consisted of short bundles running in different directions. Occasionally, however, the collagen fibers were seen to be organized into apparently normal Haversian systems. We found that abnormal collagen patterns remained unchanged after large doses of vitamin D. Figure 3-B shows in cross section the collagen pattern in normal bone tissue taken from the rib of a patient who expired at the age of three years. For comparison, note the collagen pattern in bone taken from a patient with vitamin-D resistant rickets (Fig. 5-B).

Microdiffraction was done on some of the transverse sections in order to study the ultrastructure and orientation of the crystallites. Both the highly mineralized trabeculae and those showing low mineral content displayed an apatite pattern with the same dimensions of the unit cell that is found in ordinary bone (a-axis 9.41 Angström units, and c-axis 6.87 Angström units) [5]. No orientation of the crystallites could be demonstrated.

## DISCUSSION

Despite research, the pathogenesis of vitamin-D resistant rickets continues to remain obscure.

Previous histological study of skeletal tissue (the costochondral junction) in vitamin-D resistant rickets has revealed similar changes that have long been identified with

FIG. 3-A

Figs. 3-A and 3-B: Ground transverse section 100 microns thick from the bony part of a rib of a three-year-old child; there is no evidence of skeletal disorder.

Fig. 3-A: Microradiogram showing the outer circumferential lamellae and compact bone tissue; the Haversian systems show varying amounts of mineral salts. Several resorption cavities are seen (× 15).

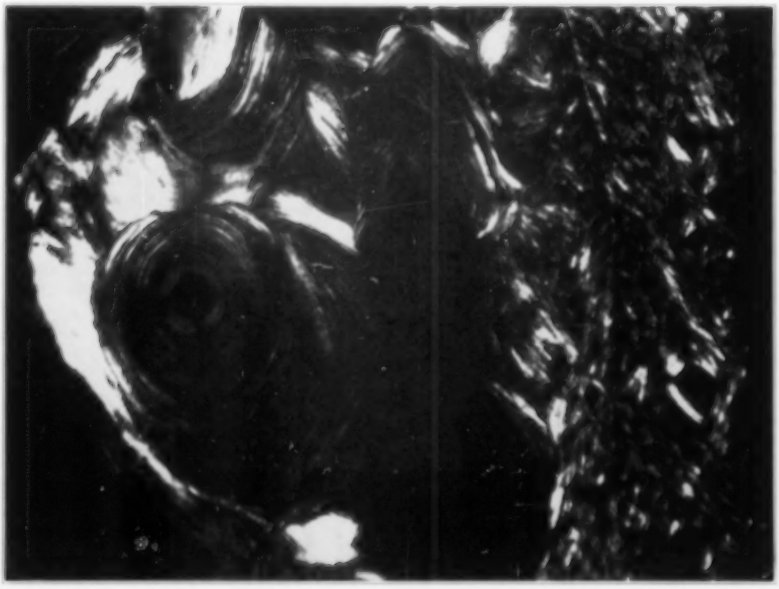

FIG. 3-B

The same section photographed in polarized light after decalcification. The area shown corresponds to the right one-fourth of the microradiogram shown in Figure 3-A. The well-organized collagen pattern of the Haversian system is seen at the left, and in the circumferential lamellae small bundles of collagen fibers run in different directions (× 46).

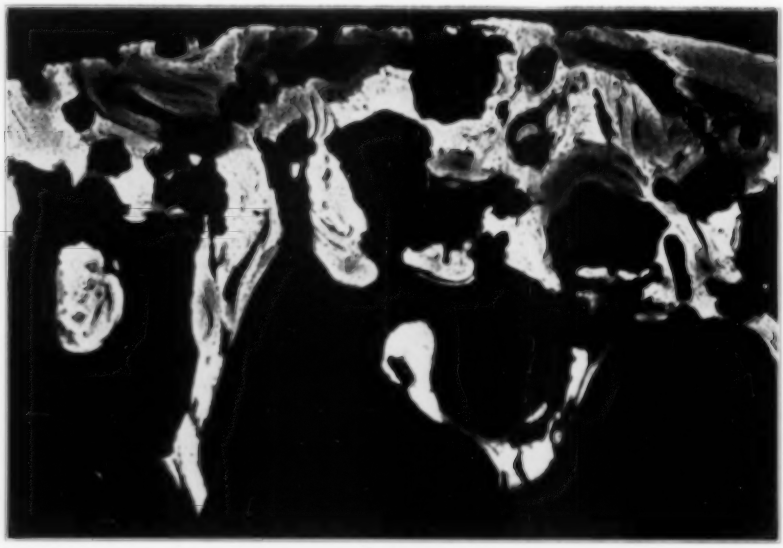

FIG. 4-A

Figs. 4-A and 4-B: Case 4. Ground transverse section 100 microns thick from a biopsy specimen of the long part of a rib.

Fig. 4-A: Microradiogram showing abnormal cortical bone. No definite outer circumferential lamellae and only a few well-developed Haversian systems are seen (× 16).

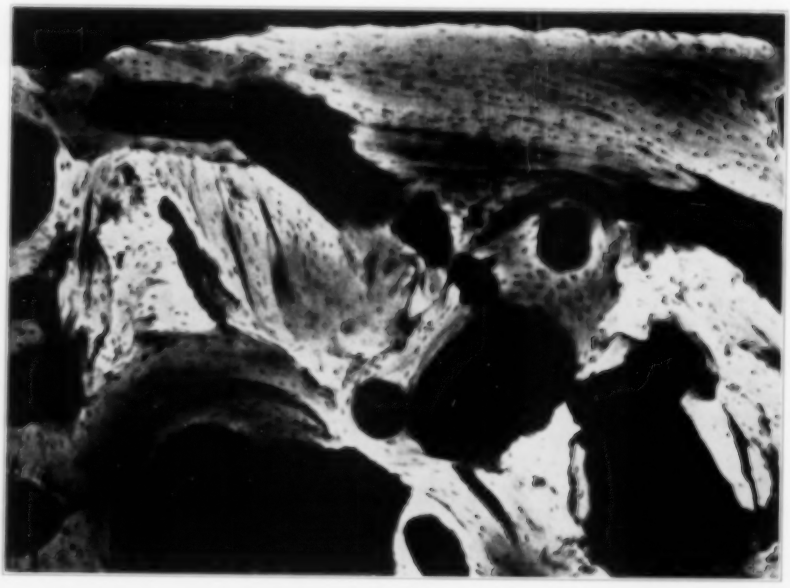

FIG. 4-B

High-power microradiogram showing many areas of resorption and irregular bone trabeculae with great differences in mineralization. Areas of different degrees of mineralization form a mosaic-like pattern. Some trabeculae are seen to have a lamellar structure (× 51).

FIG. 5-A

Figs. 5-A and 5-B: Case 1. Ground transverse section 130 micra thick of biopsy material from the rib.

Fig. 5-A: Microradiogram showing abnormal compact bone. No normal outer lamellae and no definite Haversian systems are seen. The bone tissue is composed of irregular trabeculae with highly varying mineral content (× 47.5).

FIG. 5-B

Photomicrograph taken in polarized light after decalcification. Note the small irregular bundles of collagen fibers running in different directions (× 47.5).

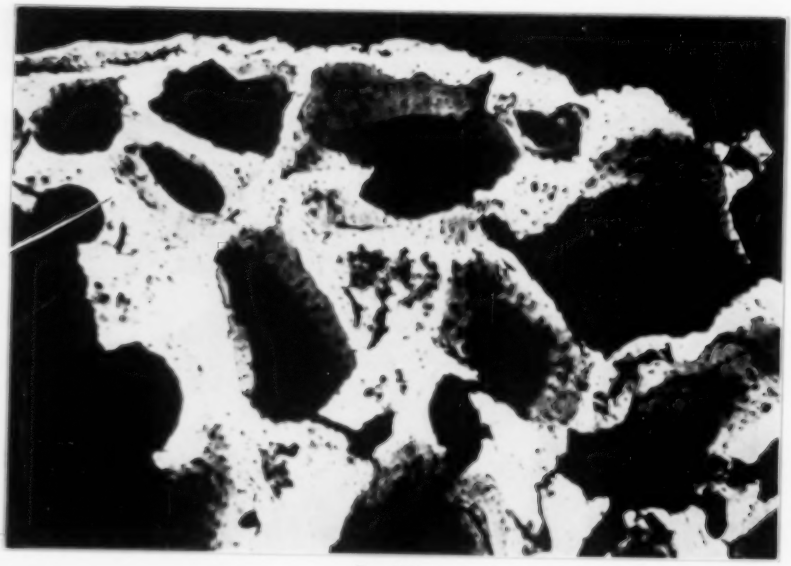

FIG. 6-A

Figs. 6-A and 6-B: Case 3. Ground transverse section 120 microns thick of compact bone tissue from tibia.

Fig. 6-A: Microradiogram showing the abnormal structure of the compact bone. The periosteal border is seen in the upper part of the microradiogram. Numerous resorption cavities are seen and the bone tissue shows great variation in mineral content. In most of the resorption cavities are newly formed areas with low mineral-salt content. The osteocytes are often surrounded by a large irregular zone containing small amounts of mineral salts or none at all (× 22).

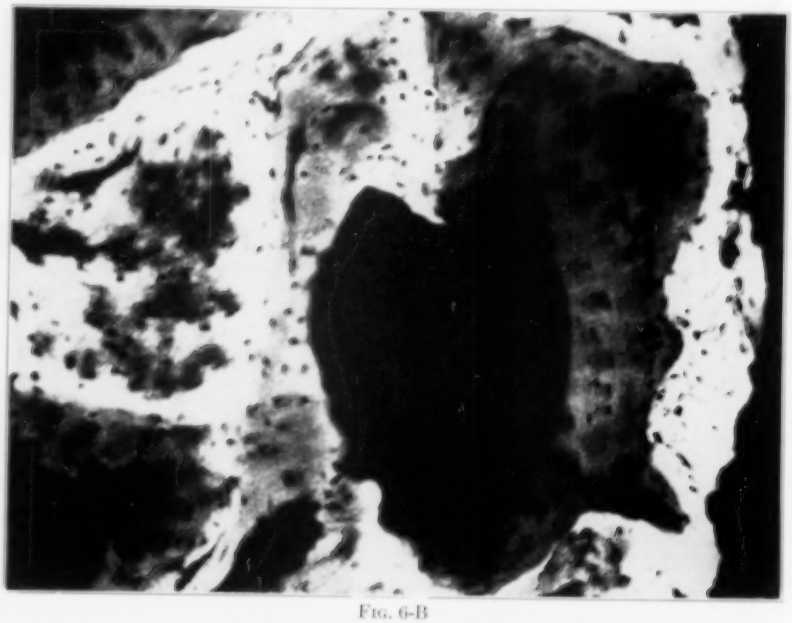

FIG. 6-B

Detail of microradiogram shown in Figure 6-A (× 55).

FIG. 7-A

Case 3. Ground transverse section 120 micra thick of bone tissue from tibia. Microradiogram of bone trabeculae shows great variation in mineralization and slight mosiac structure in some areas. In the mineralized area at the left a lamellar organization is seen (× 75).

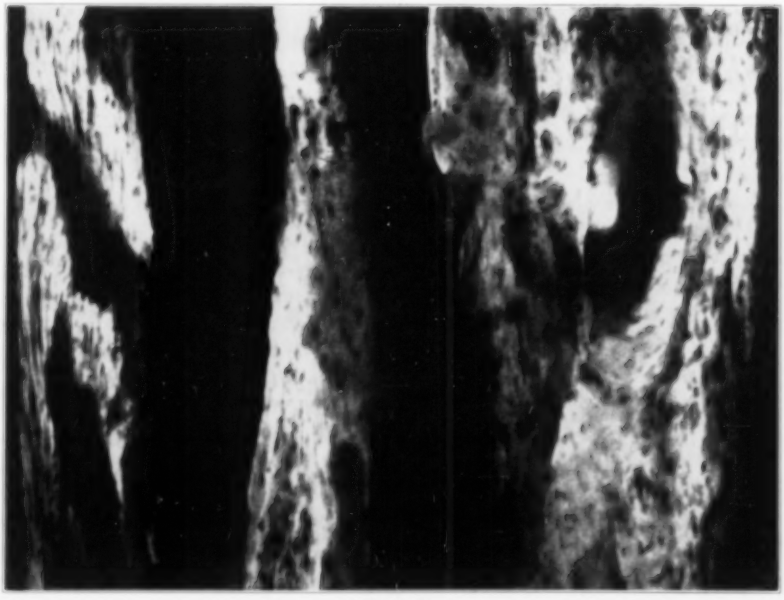

FIG. 7-B

Ground 140-micra thick longitudinal section of bone tissue from tibia showing irregular mineralization and lamellar structure (× 75).

vitamin-deficiency rickets [1]. In addition, metabolic studies made before and during vitamin-D treatment have shown that there is, grossly, the same metabolic disturbance in both forms of rickets [2, 11, 16]. However, these findings cannot be considered evidence that the cause of vitamin-D resistant rickets is a lack of vitamin-D action, as in vitamin-deficiency rickets, since these skeletal changes and metabolic changes are not pathognomic.

The high urinary phosphorus clearance in vitamin-D resistant rickets [10, 14] has been thought to indicate intense parathyroid gland activity. The removal of a hyperplastic parathyroid gland was found to result in marked but temporary change in the blood chemistry of a patient with vitamin-D resistant rickets [1]. However, subsequent roentgenograms showed no secondary healing of the rickets. Treatment with massive doses of vitamin D [1] or with dihydrotachysterol [12] has been found to increase the content of mineral salts in the skeleton. However, the persistence of an abnormal structure of the bone tissue [1] and the immediate start of demineralization when therapy is discontinued [16] show that the condition cannot be completely cured even with massive doses of vitamin D.

Just as in an earlier investigation, the histological findings in the costachondral junctions in our cases were those suggestive of severe human rickets. However, the cross section from compact bone (a portion of the tibia) from a patient who had been treated with high doses of vitamin D showed a pattern which was not consistent with rickets; there was a tendency to the formation of a mosaic structure resembling that seen in Paget's disease. Such changes were also observed in the bony part of the rib from a biopsy specimen taken before treatment was started.

As has been demonstrated earlier, the abnormal texture of the diaphysis of the long bones seen on clinical roentgenographic examination was not normalized by a treatment with massive doses of vitamin D [1]. Despite almost normal mineralization, the lack of normal, compact bone was established by microradiography of a specimen of bone obtained from a patient's tibia after vitamin-D treatment. The bone structure was found to be abnormal with an enormous variability of the calcium content in different areas. Although increased mineralization was seen roentgenographically, microradiography revealed the same structural abnormalities that were seen in the skeletal tissue of patients not treated with vitamin D. This finding supports the assumption that vitamin D, even in extremely large doses, has no direct effect upon the skeleton in vitamin-D resistant rickets. The deposition of mineral salts after treatment with vitamin D is only secondary to an increase of the calcium-phosphorus product of serum. Vitamin D results in deposition of mineral salts in the skeleton but the abnormal structure of the bone tissue is not normalized and thus vitamin D does not cure the disease.

In some areas with low calcium content, as well as in areas with high mineralization, the bone tissue in vitamin-D resistant rickets showed much wider calcium-free regions around the osteocytes than is seen in normal bone. Around some osteocytes the border of the calcified tissue was not sharply defined as in normal bone but was irregular and indistinct. A similar pattern has been previously observed in experimental hyperparathyroidism in dogs [7]. The findings were the same in all patients whether treated with vitamin D or not. When examined histologically, the organic component did not appear abnormal. Whether this abnormal calcification occurs during the formation of the bone tissue, or whether the phenomenon is the result of a dissolution of bone minerals from the osteocytes—that is, some kind of halisteresis—cannot be deduced from this investigation.

The microradiographic pattern is consistent with the hypothesis that in this condition there is lively remodelling of the bone tissue with intense absorption and new deposition of mineral salts in both untreated and treated patients. This suggestion is supported by the results obtained by Bauer, Carlsson, and Lindquist, who, from isotopic experiments *in vivo*, concluded that there is normal accretion of bone salts in untreated vitamin-D resistant rickets, but low accretion in vitamin-deficiency rickets.

The results presented give no information about the cause of the abnormalities observed. The process is apparently more complicated than in vitamin-deficiency rickets. A disturbance in the balance between new deposition of bone minerals and resorption processes seems to be present. The extremely low serum phosphorus level probably indicates that the pathological process is not solely connected with skeletal metabolism, but also involves the organs regulating calcium and phosphate metabolism. Thus, Albright and his associates have given evidence of secondary hyperparathyroidism being present in vitamin-D resistant rickets [1]. There is a possibility that the existing secondary hyperparathyroidism not only modifies the blood chemistry but also exerts an influence on the skeletal disorder. Thus at least some features of the morphological changes of the skeletal tissue in vitamin-D resistant rickets could possibly be attributed to disturbed parathyroid function.

## SUMMARY AND CONCLUSIONS

Histological and biophysical studies of bone tissue in primary vitamin-D resistant rickets have shown structural features that in this disease differ from those found in ordinary human rickets. Compact bone has been found to show structural changes resembling those found in Paget's disease. These changes are characterized by an abnormal mosaic-like pattern of bone tissue which is not affected by large doses of vitamin D. Histological examination of the costochondral junction of these patients, however, reveal abnormalities similar to those found in ordinary vitamin-D deficiency rickets.

It may be concluded that vitamin-D resistant rickets is a well defined, genetically determined clinical and pathological entity, different from ordinary rickets. Treatment with vitamin D in massive doses has no direct effect upon the skeleton in vitamin-D resistant rickets. Vitamin D improves the possibilities for a deposition of mineral salts in the skeleton by its hypercalcemic effect, but does not influence the morphology of the skeletal disorder and does not cure the disease.

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## DISCUSSION

### Spontaneous Rupture of Extensor Tendons

*(Continued from page 1217)*

joints, avulsion of the central slip of the extensor mechanism (boutonnière deformity), avulsion of the extensor tendon to the distal phalanx (mallet deformity), tenodesis of the flexor tendons in the fingers, intrinsic muscle contracture, and spontaneous tendon rupture.

As the authors indicated, spontaneous tendon ruptures occur as the result of attrition. I would like to add that they occur only in that part of the tendon which is surrounded by the synovial sheath and in which, therefore, reparative fibroplasia is suppressed. They never occur in that part of the tendon which is surrounded by paratenon and which, therefore, has great reparative ability.

It certainly seems probable that dorsal subluxation of the distal end of the ulna could mechanically increase the stress on the finger extensors, particularly the medial extensors, leading to gradual fraying followed by rupture. Perhaps the pronation deformity so often associated with dorsal subluxation of the distal end of the ulna adds to the mechanical stress exerted on the tendons in this area.

I would like to compliment the authors on their method of treating these tendon ruptures. I feel that it is far wiser to do a simple operation, such as they have suggested, than to do a more complicated tendon-grafting operation. Certainly, it is good surgical judgment to resect the distal end of the ulna and thereby remove the mechanical derangement which exists at the dorsum of the wrist.

Dr. Lot D. Howard, Jr., San Francisco, California: This paper by Dr. Straub and Dr. Wilson should make us all pause to re-evaluate our cases of tendon rupture.

The sudden rupture of a normal tendon as a result of forced effort or stubbing is a comparatively simple problem from the standpoint of both diagnosis and treatment.

Sudden rupture during light activity signifies that the tendon has been weakened as a result of disease, frictional trauma, or reduction in volume secondary to partial laceration.

The role of rheumatic disease in tendon rupture can be twofold. Joint involvement can set up a mechanical situation in which friction occurs, followed by rupture. Involvement of the tendon sheath and of the tendon itself can so weaken the tendon that spontaneous rupture following light effort can occur.

In this latter category, sudden rupture is less common than the gradual loss of tendon function due to slackening or elongation of the tendon. Tendon attenuation or "finger drop", as I choose to call it, results from the growth of granulation tissue into the tendon with gradual dissolution of the normal tendon fibers. Tendon scar, produced to combat the growth of granulation tissue, yields under the constant strain, resulting in elongation of the tendon, a response similar to the yielding of a tendon at its juncture following repair.

This phenomenon may be readily recognized at surgery. In the area of elongation, the normal white tendon fibers disappear and the tendon narrows down to a spindle of pseudo-tendon; the narrowing extends for about an inch, after which the tendon re-expands and normal fibers again appear.

This description applies to all the long tendons, both flexor and extensor. The process may be punctuated by the sudden complete rupture of the weakened tendon.

*(Continued on page 1345)*

# A Morphological and Histochemical Study of Osteoclasts*

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The purpose of this investigation was to study morphological and histochemical characteristics of osteoclasts in normal and in *ia* animals. It has been shown [21] that, although appositional growth of bone is normal in the *ia* strain of rats, there is minimal resorption. It seemed possible that a study of the osteoclasts in these *ia* animals might show interesting differences from the osteoclasts in normal animals, and at the same time, add to our knowledge of normal osteoclasts.

## REVIEW OF THE LITERATURE

The literature contains no report of investigations into the three-dimensional aspects of the morphology of osteoclasts based on the study of serial sections. Histochemical studies of nucleic acids in osteoclasts are also lacking.

There is general agreement that osteoclasts are multinucleated giant cells which vary greatly in size and in number of nuclei. They are usually seen where bone is undergoing resorption and are frequently found in deep grooves — Howship's lacunae — which have the appearance of erosion in the bone.

The concept that osteoclasts are responsible for the resorption of bone tissue was proposed by Kölliker in 1873, who first named and described these cells. The exact origin and function of the osteoclasts is still a disputed subject, and a number of theories have been proposed [11, 18].

The result of Kölliker's study of the function of osteoclasts was the formation of the theory most widely accepted today—that osteoclasts are the primary agent in bone resorption. Von Recklinghausen was of the opinion that osteoclasts are the result of a fusion of bone cells and as such cannot contribute to the process of resorption. Ruth found no increase in osteoclasts in the pubic symphysis of pregnant guinea pigs, and inferred that these cells have no direct function in resorption of bone.

Several authors [1, 3, 6] have stated that osteoclasts are produced by the fusion of osteoblasts or undifferentiated mesenchymal cells. Others [12], after studying rapid bone formation and destruction following the administration of parathyroid extract in mammalian bones, concluded that osteoclasts, osteoblasts, and osteocytes may be considered to be temporary functional states of the same cell type. Still others [10, 15] ascribed the origin of the osteoclast to the fusion of histiocytes or mobile wandering cells.

In 1941, Greep first described the *ia* strain of rats in which the incisors failed to erupt. It was later determined that this failure of the incisors to erupt was due to generalized lack of physiological bone resorption [21]. This abnormality was found to be inherited as a simple Mendelian recessive factor. Although osteoclasts are present in normal numbers in these animals, bone resorption is deficient.

## MATERIAL AND METHODS

### *Morphological Study*

This study was based on ten five-day-old littermate rats, of which five were *ia* animals and five were normal. The animals were sacrificed and decapitated, the heads were fixed

* This investigation was supported in part by a research grant from the National Cancer Institute of the National Institutes of Health, United States Public Health Service.

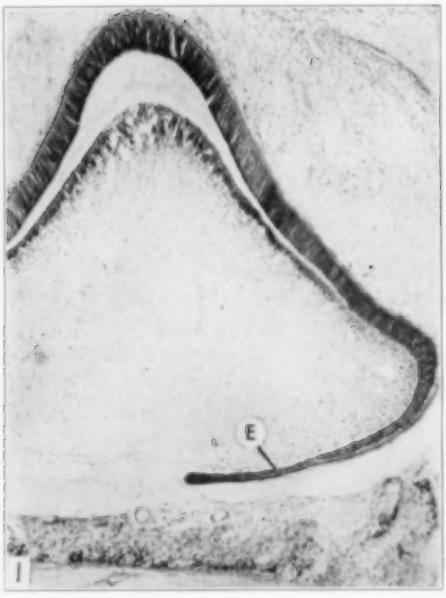


FIG. 1

FIG. 2

Figs. 1 through 4: Photomicrographs of frontal sections through the mid-region of the maxillary first molar in a normal and an *ia* animal at five days after birth.

Fig. 1: Section through the molar of a normal animal, showing the regular outline of the epithelial diaphragm (E). Osteoclasts were studied in the region of the alveolar bone (which does not stain with thionin) underlying the tooth germ (thionin stain, × 68).

Fig. 2: Section through the molar of an *ia* animal showing the irregular outline of the epithelial diaphragm (E) due to the growth of the tooth germ without concomitant resorption of the alveolar bone (thionin stain, × 85).

in 10 per cent formalin and embedded in paraffin. Serial sections were then cut through the alveolar region of the molars, since osteoclasts are known to be present in the area of developing tooth sockets. The sections were stained with hematoxylin and eosin, and camera-lucida drawings were made of single osteoclasts following them through serial sections (Figs. 5-A and 5-B).

*Histochemical Study*

A litter of eight five-day-old animals, four *ia* and four normal littermates, born of a heterozygous female and a homozygous male, were sacrificed by the perfusion-fixation method through the heart, described by Koenig, Groat, and Windle. The animals were perfused with a washing fluid (NaCl, 0.9 gram; gum acacia, 0.69 gram; and water 98.4 milliliters), which was followed by the fixing solution (the same NaCl and gum acacia proportions in 98.4 milliliters of 10 per cent formalin). After perfusion, the animals were decapitated and placed in a solution of isotonic 10 per cent formalin for more complete fixation and for storage.

The heads of these animals were embedded in paraffin, and serial sections ten micra thick were cut in a frontal plane through the region of the alveolar bone of the upper first molar (Fig. 1).

Slides containing five sections arranged in serial order were stained consecutively as follows:

1. Hematoxylin and eosin;
2. Thionin at a pH of 4.46 according to the method of Windle, Rhines, and Rankin,

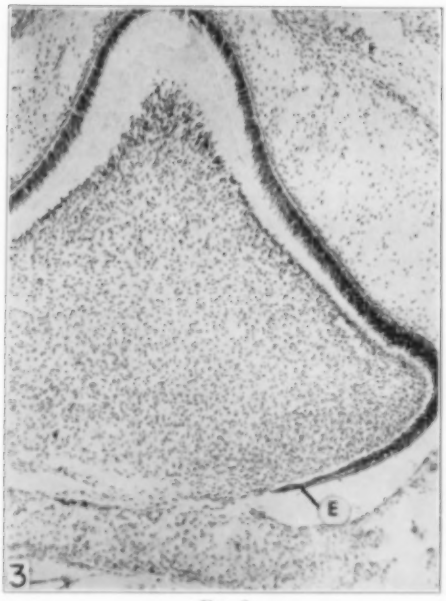


FIG. 3

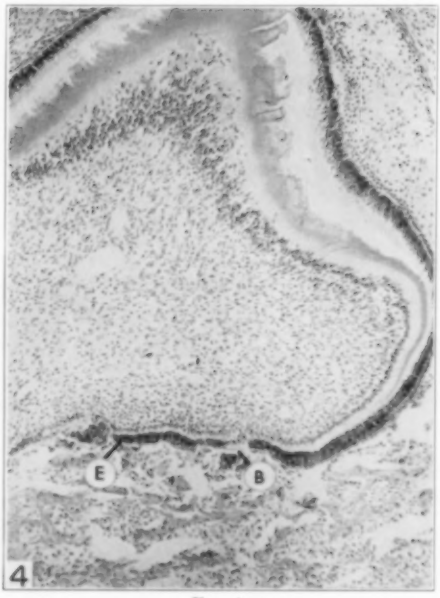


FIG. 4

Fig. 3: Section through the molar of a normal animal showing the regular outline of the epithelial diaphragm (E) (Feulgen stain, × 68).

Fig. 4: Section through the molar of an *ia* animal showing the irregular outline of the epithelial diaphragm (E) and the proximity of this structure to bone tissue (B) (Feulgen stain counterstained with fast green, × 68).

modified by LaVelle (Figs. 1 and 2). The heads of two additional animals were fixed by the Altmann Gersh freeze-dry method. The tissues were frozen in isopentane chilled in liquid air at −140 to −150 degrees centigrade and were then dehydrated *in vacuo* at −32 degrees centigrade. The heads were embedded in paraffin and sections were cut at a thickness of ten micra. Some of these sections were subjected to ribonuclease (0.5 milligram per cubic centimeter of distilled water) and allowed to remain for ten hours at 25 degrees centigrade. Control slides were subjected to distilled water for a similar period at the same temperature. All of these slides were then stained with thionin. It was found that the cytoplasm of the cells in the sections subjected to ribonuclease did not react with thionin, while the nuclei stained blue. In the control slides, both the nucleus and the cytoplasm reacted to the stain. This would indicate that under normal circumstances the cytoplasmic ribonucleic acid reacts to thionin by staining.

3. The Feulgen technique, in which the Coleman and Bell basic fuchsin is used, and the procedure described by Cowdry for desoxyribonucleic acid (Fig. 3). In order to distinguish the osteoclasts more readily in slides stained by this method, some of the sections were counterstained with fast green FCF according to the method described by Lillie (Fig. 4). The cellular cytoplasm and bone portions of these sections stained green.

In all staining techniques, normal and experimental material was stained in the same vessel to ensure as accurate control as possible.

After staining, cover slips were mounted on the slides, a terpene polymer resin, Hartman Leddon "H. S. R." being used.

## FINDINGS

### *Normal Animals*

Three-dimensional reconstructions based on drawings from serial sections revealed that most of the osteoclasts were larger and extended more widely over the surface of the

bone than has been previously suspected or described. The cells had a very extensive and irregular outline (Figs. 5-A and 5-B). In many instances they showed long processes (Fig. 5-A, 7) which either united with similar processes of adjoining osteoclasts to form a syncytium, or ended freely. Also, it was surprising to find that individual cells were not confined either to a single lacuna or to a single surface of bone trabeculae, but extended over several trabeculae and often occupied several lacunae.

The cytoplasm of the cell was generally in close approximation with the surface of the bone, so that in sections stained with hematoxylin and eosin it was sometimes

FIG. 5-A

Figs. 5-A and 5-B: Photographs of camera-lucida tracings through serial sections of osteoclasts in a normal animal at five days of age. Numbers 1 through 17 represent serial sections through one ostoclast, and the following numbers 1 through 7 represent serial sections through another osteoclast. Each section was ten microns thick. Stippled area—bone tissue; black—osteoclasts (× 150).

difficult to recognize the demarcation between the two. In such cases the osteoclasts might have been overlooked if successive sections had not been examined carefully and compared. Occasionally a cell appeared to lie at some distance from a bone trabecula, but examination of succeeding sections revealed that a major portion of the cytoplasm was actually in contact with bone tissue (Fig. 5-A, *8*).

The nuclei of the osteoclasts studied in this series were spherical or ovoid in shape, and contained one or more nucleoli. In the smaller osteoclasts, the nuclei tended to aggregate in the center of the cell. In larger cells, the distribution of the nuclei was less regular and large areas of cytoplasm appeared as nucleus-free (Fig. 5-A, *6*). In large osteoclasts, the cell processes were usually nucleus-free; thus, in some sections a cell was represented only by a mass of cytoplasm lying adjacent to the bone trabecula. Studied in a single section, a cell, by its location and shape appearing to be an osteoblast (Fig. 5-B, *1*), some-

FIG. 5-B

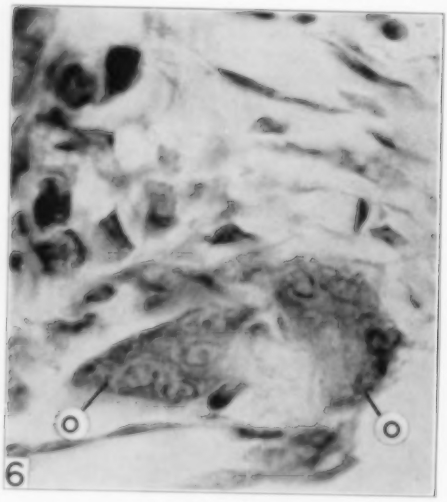


FIG. 6

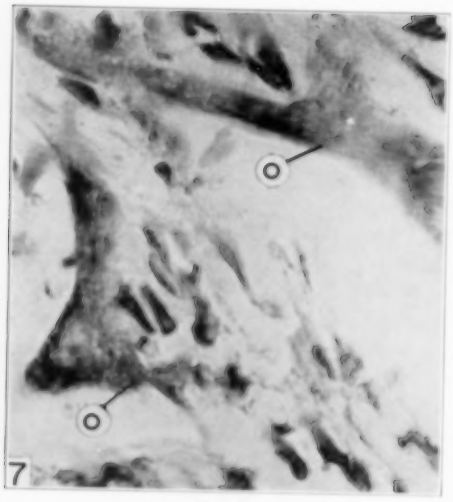


FIG. 7

Figs. 6 through 9: Photomicrographs of sections through osteoclasts in the region of the alveolar process in normal and *ia* animals (thionin stain, × 1200).

Figs. 6 and 7: Osteoclasts (*O*) in an *ia* animal.

Figs. 8 and 9: Osteoclasts (*O*) in a normal animal. Note the intense staining of the cytoplasm of the normal osteoclasts as contrasted to the comparatively lighter staining cytoplasm of the *ia* osteoclasts.

times proved to be an osteoclast when examined in serial section. This occurred when a single section had been cut through a process of the osteoclast which happened to contain one nucleus.

*ia Animals*

Despite the fact that the *ia* strain of rats is characterized by a marked deficiency of bone resorption, the osteoclasts observed in them appeared to be normal in number and distribution, and their morphological characteristics were similar to those of normal controls.

*Histochemical*

Particular note was made of the intensity of cytoplasmic and nucleolar staining with thionin, and of the appearance of the nuclear and nucleolar membranes which were stained by the Feulgen technique.

*Normal Animals*

*Cytoplasm and nucleolus (ribonucleic acid sites):* The cytoplasm of normal osteoclasts stained intensely with thionin and showed a marked aggregation of coarse basophilic granules throughout its structure, giving it in some instances an almost homogeneous dark appearance (Figs. 8 and 9). Although various osteoclasts reacted with different intensities, most of them showed a very dark cytoplasmic stain. The nucleoli were also prominent, and, like the cytoplasm, showed marked basophilia when stained with thionin (Fig. 9).

*Nucleus and perinucleolar bodies (desoxyribose nucleic acid):* The nuclear outline was distinct in specimens stained by the Feulgen technique. The chromatin appeared as small rounded bodies in the nuclear sap (Fig. 10). The nucleus presented a smooth, regular outline and usually, in the center of the nucleus, intensely staining perinucleolar bodies were distinct around a lighter staining nucleolus (Fig. 10).

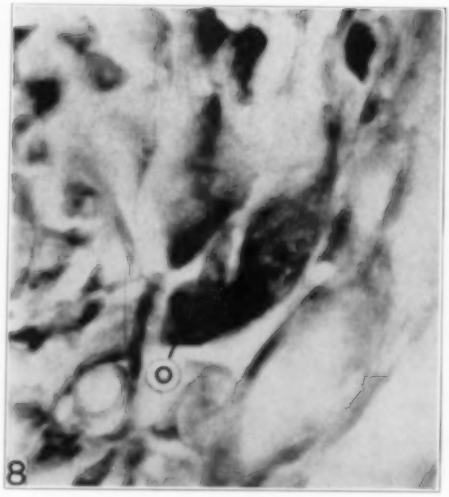


FIG. 8

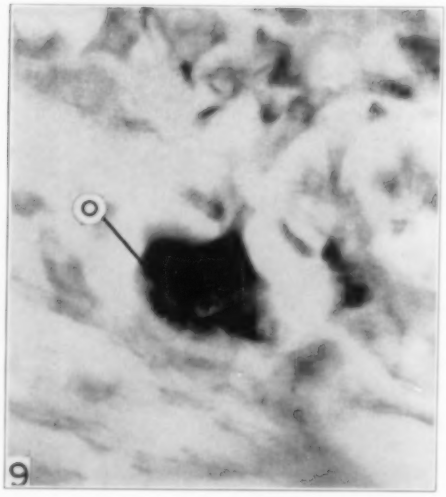


FIG. 9

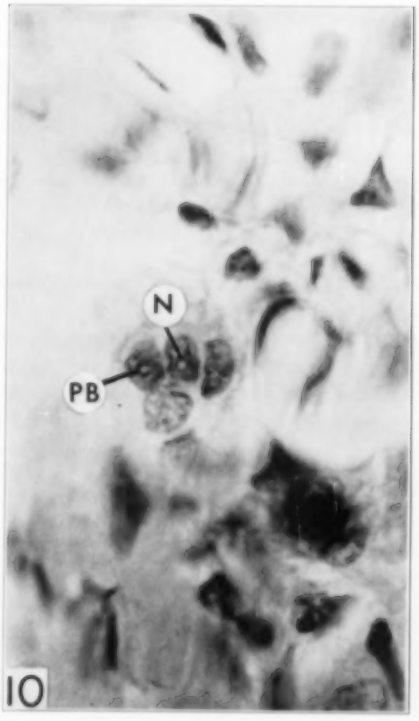


FIG. 10

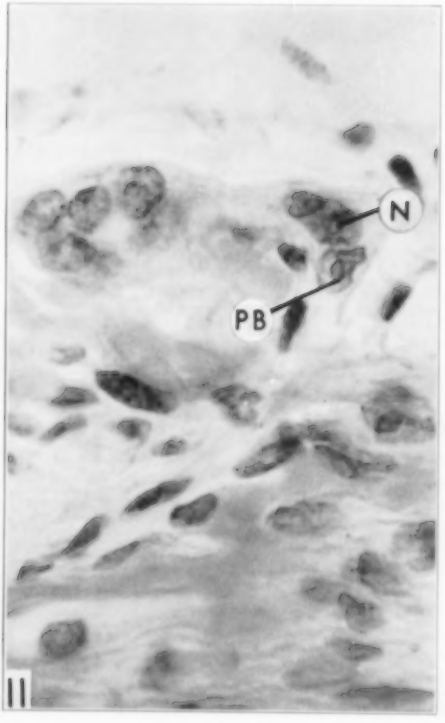


FIG. 11

Figs. 10 and 11: Photomicrographs of sections through osteoclasts in the region of the alveolar process in normal and *ia* animals (Feulgen stain counterstained with fast green, × 1000).

Fig. 10: Osteoclast in a normal animal showing nucleolus (*N*) and perinucleolar bodies (*PB*).

Fig. 11: Osteoclast in an *ia* animal showing nucleolus (*N*) and perinucleolar bodies (*PB*).

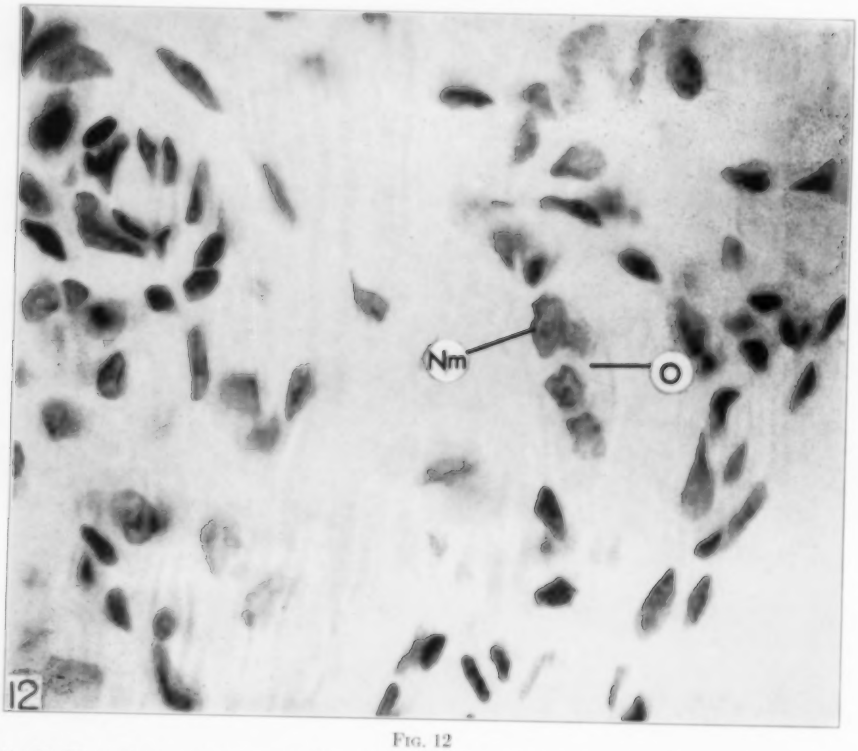


FIG. 12

Fig. 12: Photomicrograph of a section through an osteoclast (*O*) in the region of the alveolar process in an *ia* animal. Note the marked irregularity of the nuclear membrane (*Nm*) (Feulgen stain, × 1000).

*ia Animals*

*Cytoplasm and nucleolus (ribonucleic acid sites):* The cytoplasm of the osteoclasts in the *ia* animals stained far less intensely with thionin than did the normal cells, and the granules were dispersed (Figs. 6 and 7). Although the osteoclasts of *ia* animals showed varying degrees of staining intensity, the predominating number stained very lightly with thionin and very few approached the intense basophilia seen in the normal cells. The nucleoli were distinct and seemed essentially the same as the nucleoli of normal osteoclasts.

*Nucleus and perinucleolar bodies (desoxyribose nucleic acid sites):* In the *ia* osteoclasts the nuclear membrane was quite distinct but frequently showed a wrinkled outline (Fig. 12). Some chromatin material was present in the nuclear sap. The nucleoli and perinucleolar bodies were similar to those seen in the cells of the control animal (Fig. 11).

## DISCUSSION

*Origin of Osteoclasts*

Although this study does not attempt to postulate a definite theory of the origin of osteoclasts, it can at least present evidence that they do not originate from liberated osteocytes as has been thought [12], and that they are not a *result* of bone resorption.

Bone resorption is greatly retarded in *ia* rats and, therefore, liberation of osteocytes does not occur to any great extent. Nevertheless, osteoclasts are present in *ia* rats in large numbers. It has been claimed by several authors [9, 19, 22] that destruction of bone begins as a softening and liquefaction of the ground substance and is followed by a leaching out (halisteresis) of the bone salts. These authors claimed that osteoclasts are nucleated cyto-

plasmic masses which result from the fusion of the bone cells. Ruth observed extensive resorption of bone but relatively few osteoclasts in a study of the changes of the pubic symphysis of pregnant guinea pigs, and suggested that the resorption of bone is the stimulus to the formation of these cells.

If the osteoclasts were the result of bone resorption, one would not expect to see them in the *ia* skeleton where destruction of bone tissue is minimal. It is evident from these observations of the *ia* bone that, whatever their function or origin, these cells do not originate from liberated osteocytes, and that they are not formed after, but appear before, the resorption of bone.

*Role of Osteoclasts in Bone Resorption*

Some authors [12, 20] have observed that osteoclasts are not always seen in areas of bone resorption, and there is no evidence that the osteoclast is responsible for bone destruction. The present study shows that the presence or absence of osteoclasts in areas of bone resorption cannot always be determined in non-serial sections. Non-nucleated cytoplasmic extensions of these multinucleated cells, lying in lacunae, are easily overlooked in single sections. In a single section cut through an osteoclastic process containing one nucleus, the one nucleus will sometimes appear as a uninucleated cell and may, therefore, be mistaken for an osteoblast or a liberated osteocyte.

Osteoclasts in *ia* animals do not differ from normal osteoclasts in shape, size, or in the distribution of their nuclei. However, the mere presence of osteoclasts does not mean that resorption of bone does or can occur, since in the *ia* animals numerous osteoclasts are present but bone resorption is minimal. It is certain that genetic influence is a most important factor in bone resorption. However, the defective genes in the *ia* animals may act not only on the osteoclasts, but also on the parathyroid or other glands. It was found that injections of parathyroid hormone in the *ia* rats produced bone resorption[2]. This might suggest the possibility that, for normal resorption of bone tissue, it is necessary to have a certain level of parathyroid hormone in addition to the presence of osteoclasts. Further investigations of the functional activity and morphology of the parathyroid glands in *ia* animals are indicated.

*Possible Significance of Histochemical Staining of Osteoclasts*

It was found that the cytoplasm of normal osteoclasts stained intensely with thionin, indicating a heavy concentration of cytoplasmic ribonucleic acid. The cytoplasm of *ia* osteoclasts differed markedly from the normal in that the cytoplasmic staining with thionin was very light.

Caspersson and Brachet considered the existence of a relationship between ribonucleic acid and protein synthesis of a cell. An outstanding example of the evidence for this theory is the fact that the cells of the silk gland of the silkworm caterpillar are rich in ribonucleic acid, and the only known function of these cells is the secretion of the protein, silk.

McLean considered the action of a chelating agent, serum vitellin, a phosphoprotein, in the resorption of bone and suggested the possibility that this substance is secreted by the osteoclasts. If this is correct, it is possible that normal osteoclasts may play a role in the synthesis of an unknown protein as evidenced by their rich cytoplasmic ribonucleic acid content but, due to some undetermined deficiency, the cells of the *ia* animals are incapable of such synthesis. If parathyroid hormone is given in massive doses, localized resorption of *ia* bone does occur [2], indicating that parathyroid hormone is necessary for the activity of osteoclasts. In order to investigate this subject, further histochemical studies of osteoclasts in *ia* animals subjected to doses of parathyroid hormone are necessary.

While the wrinkling of the nuclear outlines of the *ia* osteoclasts may be due principally to a fixation artifact, it is interesting to note that in the normal specimens, which were

fixed according to the same procedure, the nuclei of the osteoclasts presented a smooth outline. The possibility suggests itself that the nucleus aids in the secretion of the cell, but that, due to some block, genetic or otherwise, the nuclei of the *ia* osteoclasts are unable to participate normally in the secretion process.

## SUMMARY AND CONCLUSIONS

Osteoclasts of normal and *ia* rats were subjected to morphological and histochemical studies. The three-dimensional aspects of the morphology of these cells were studied by means of camera-lucida tracings of serial sections of osteoclasts from the region of the sockets of developing teeth. The nucleic acids in the osteoclasts were studied in sections cut through the alveolar region of five-day-old normal and five-day-old *ia* rats. The sections were stained by the Feulgen technique and with thionin.

1. No differences were observed in size and shape between the osteoclasts of normal and of *ia* animals.

2. The osteoclasts were found to be much larger and their cytoplasmic extensions much wider than has been previously suspected. In some areas, the osteoclasts formed a syncytium and large areas of their cytoplasm were found to be nucleus-free. Osteoclasts possess long processes which may or may not contain nuclei. Thus, in non-serial histological sections passing through the processes of these cells, the osteoclastic cells may be overlooked or mistaken for osteocytes or osteoblasts lying in areas of resorption.

3. The cytoplasm of the normal osteoclasts stained more intensely with thionin than did the cytoplasm of the *ia* cells. The possibility of decreased protein synthesis by *ia* osteoclasts is considered.

4. Nucleoli were present in the nuclei of both normal and *ia* osteoclasts with no apparent difference between the two.

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## DISCUSSION

### Spontaneous Rupture of Extensor Tendons

*(Continued from page 1334)*

The pathological process of tendon dissolution readily explains, in my opinion, the common finger deformities which are found in hands with rheumatoid arthritis. When the process is localized at the level of the distal joint, slow dissolution of the extensor tendon results in drop-finger deformity, identical to that produced by traumatic rupture, laceration, or thermal burn. At the mid-joint level, boutonnière deformity results. Once any portion of the extensor aponeurosis yields, intrinsic muscle imbalance creates a deformity; secondary soft-tissue or joint changes may then fix the deformity.

In the treatment of lesions in the long tendons, preventive measures should produce better results than reconstruction. Recognized rheumatic tenosynovitis which is persistent or progressive can be arrested by surgical synovectomy, following which the chances of the patient's retaining useful function are good. The use of such a procedure can be justified by the axiom of little to lose and much to prevent.

As to the reconstruction following the catastrophe of rupture, tendon-transfer procedures should be considered as they offer as much or more as the distal Y-type repair described by Dr. Straub and Dr. Wilson.

Dr. Sterling Bunnell, San Francisco, California: Those of us who have operated on patients with rheumatoid arthritis have found granulation tissue in the ligaments, aponeuroses, and tendons. In these patients muscle imbalance caused by contracture brings about the various deformities. Frequently the extensor tendons luxate into the interknuckle spaces, as a result of which they ulnar flex instead of extend the metacarpophalangeal joints. The granulation tissue found in these patients is similar to that found in patients with tuberculous tenosynovitis, and it may erode through tendons and ligaments in a similar fashion.

Dr. Leo Mayer, New York, N. Y.: A tendon should not be made too tight, for if it is, there will develop the type of constriction which results in the fifth-finger tendon standing up like a bowstring. Also, it has been shown experimentally that if a tendon is submitted to too much tension, the fibers of the muscle of that particular tendon will degenerate. The tendon must be sutured under what we call normal tension. In order to determine what the normal tension is, the tension in the corresponding tendons in the involved region of the hand should be determined, as is done by Dr. Bunnell. Another factor of importance in the treatment of tendon lesions is to prevent stretching of the tendon during repair.

# Arthrodesis of the Hip *

BY MARIO M. STONE, M.D., HABANA, CUBA

*From the Instituto de Cirugia Ortopédica, Habana*

This follow-up study presents a report of forty-one patients (twenty-three males and eighteen females) upon whom hip-joint arthrodesis with internal fixation by a plate and screws was performed for conditions other than tuberculosis during the period from April 1949 to September 1954, inclusive. Each case was analyzed carefully as to symptoms, physical findings, and progress. In order to complete the history, the patients were called in recently for an interview and examination and check roentgenograms were made. No

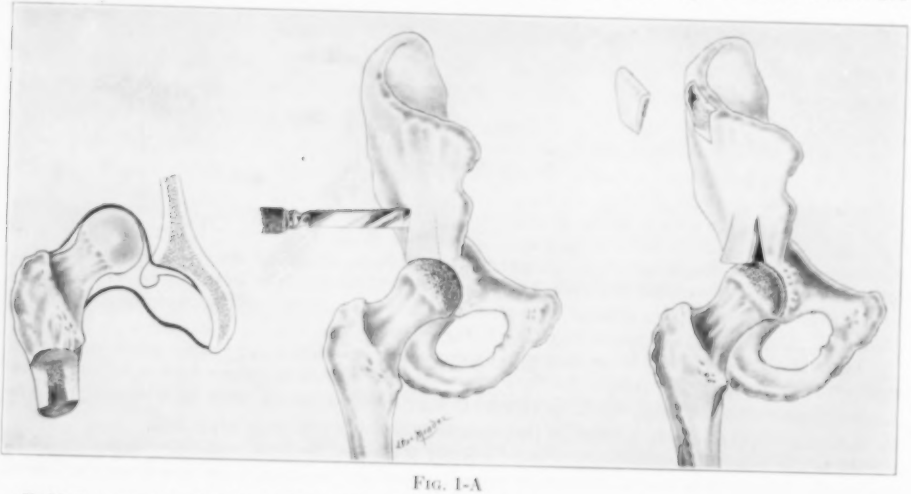

FIG. 1-A

(Left) Cross section of dislocated hip. (Center) The articular cartilage has been removed from the head of the femur and the acetabulum; the roof of the acetabulum has been deepened to permit better seating of the femur; and the head of the femur has been inserted under a long vertical iliac bone flap. (Right) A small triangular graft has been taken from the iliac crest.

patient who could not be located for follow-up examination at the end of one year has been included in the evaluation. The youngest patient operated upon was nine years old, while the three oldest were in their sixties. Eleven others were between thirty-one and sixty, and twenty-six were between eleven and thirty. There were thirty-two whites and nine Negroes.

The technique was designed especially to treat painful dislocation or severe limp following extensive hip-muscle paralysis. Fusion was done because, in the past, open reduction, shelf stabilization, and muscle transplantation have not been wholly satisfactory. In the beginning, the procedure was employed only in those instances in which there was a painful subluxation or dislocation; later, however, because marked improvement in gait was obtained in the early cases, it was used in several individuals with severe hip lurch without dislocation. At first it was believed that arthrodesis was contra-indicated in the presence of marked weakness or paralysis of the quadriceps femoris. It has been found, however, that knees with such conditions are stable if the ligaments are sound, if there is no significant flexion deformity of the joint, and if the foot and ankle are strong

* Read at the Third Triennial Meeting of the Willis C. Campbell Club, Memphis, Tennessee, October 15, 1954.

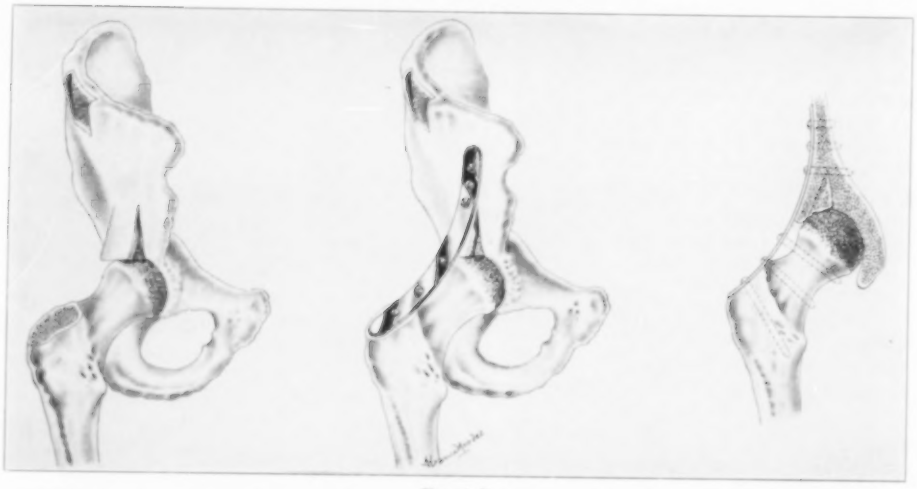

FIG. 1-B

(Left) The triangular graft has been wedged under the iliac flap. (Center) Internal fixation is secured by a bone plate which may be easily shaped with Jewett bending irons. (Right) Cross section of the arthrodesed hip.

or have been stabilized by subtalar (triple) or pantalar arthrodesis in a position of moderate equinus. The author's procedure has also been used in other conditions, such as osteo-arthritis and suppurative arthritis (Table I). Its use is not recommended in cases

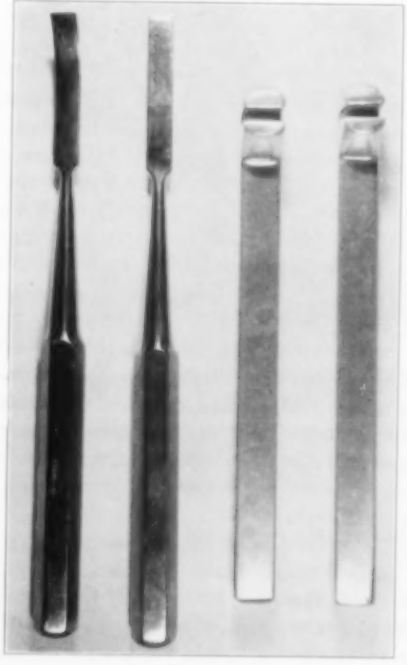

FIG. 2-A

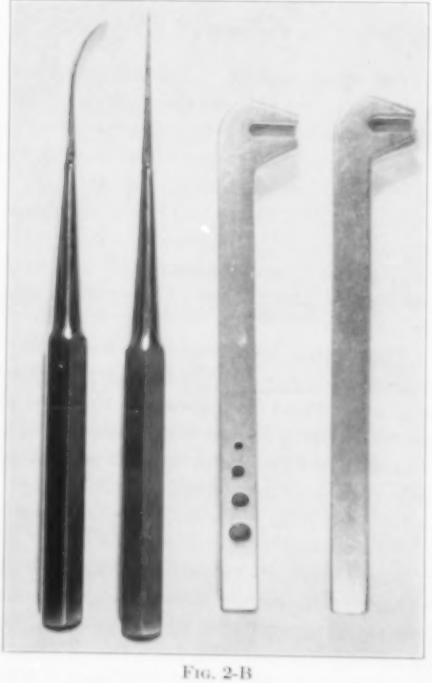

FIG. 2-B

Specially designed, extra-long, thin osteotomes used for making the iliac bone flap; Jewett bending irons for shaping the bone plate.

TABLE I

ETIOLOGY

| | | |
|---|---|---|
| 1. Poliomyelitis: | | |
| Dislocation | 19 | |
| Subluxation | 8 | |
| | | 27 |
| 2. Osteo-arthritis: | | |
| Slipped epiphysis (old) | 1 | |
| Congenital dislocation | 1 | |
| Fracture dislocation (old) | 1 | |
| Malum coxae senilis | 8 | |
| | | 11 |
| 3. Suppurative arthritis: | | |
| Old septic | 1 | |
| Old septic with pathological dislocation | 2 | |
| | | 3 |
| Total | | 41 |

of tuberculosis or in cases in which there is likelihood of a pyogenic infection becoming reactivated. The frequent failure in the past to obtain bone fusion in these patients by accepted methods of arthrodesis necessitating prolonged spica immobilization led to the development of a method for stabilizing the hip which would permit early ambulation.

It has often been said that, once the surgeon has performed a femoral-replacement arthroplasty, he has burned his bridges behind him in the event that the prosthesis fails. We do not believe that this is so, because our method of arthrodesis is ideally suited for obtaining fusion in this type of case.

*Principles of the Technique*

The upper portion of the femur is inserted under an iliac bone flap and a small triangular graft, taken from the crest, is wedged between the femur and flap. A bone plate is then applied over the flap as a means of internal fixation. Key, in 1926, secured fusion by inserting the trochanter under an iliac flap, and obtained reinforcement by means of tibial osteoperiosteal grafts. Before the plate is secured, it is important to check the desired ultimate position of the hip joint. The position used in most of the author's cases was flexion of 30 degrees (10 degrees in children), abduction of 10 degrees, and external rotation of 15 degrees. A greater degree of flexion improved the ability to sit but made walking more difficult; the reverse was true when arthrodesis was done with the joint in a position of less flexion.

The author feels that this technique, to some extent, incorporates the contact-compression factor and the biological factors of osteoclasis and osteogenesis, for a spring action is produced from above by the bone plate on the wedged iliac graft and a constant compressive force is maintained from below by the adductor muscles. This passive tension is transmitted axially and impacts the femur against the acetabulum, thereby producing excellent contact and immobilization.

## OPERATIVE PROCEDURE

No preliminary traction was used in any case. With the patient supine, a routine Smith-Petersen incision is made to gain access to the hip joint. The capsule of the anterior and superior aspects of the joint is excised in order to expose the intracapsular structures. The muscles are detached from the external surface of the ilium, and the gluteal tendons are stripped off the greater trochanter; all necrotic tissue and sequestra are removed. Cartilage is then excised from the head of the femur and the acetabulum is reamed until

FIG. 3-A

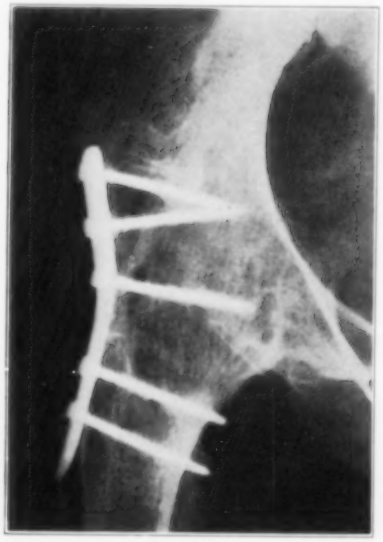

FIG. 3-B

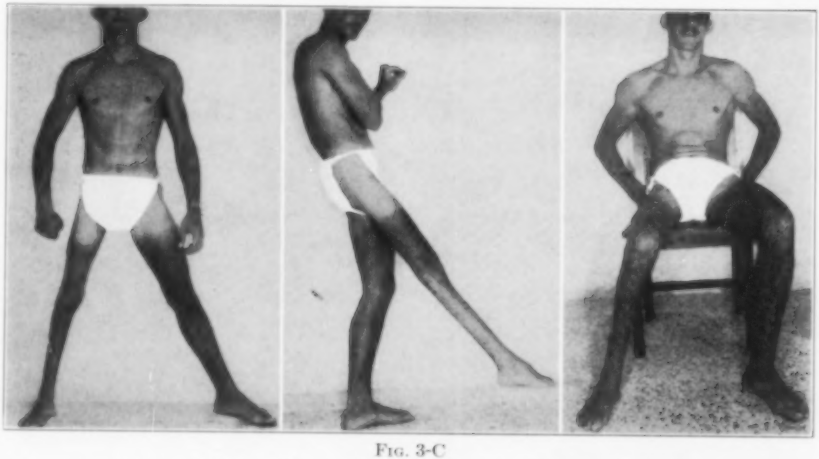

FIG. 3-C

Figs. 3-A, 3-B, and 3-C: Case 1. E. S., a patient with paralytic dislocation of the right hip (poliomyelitis) five and a half years after surgery. He is asymptomatic, works standing up ten hours a day.

healthy cancellous bone is exposed. In old suppurative dislocations the remaining portion of the femoral neck is resected at the base. The roof of the acetabulum is deepened to permit better seating of the femur. A long vertical iliac bone flap is raised, always from the primary aspect of the acetabulum, and the head of the femur is inserted under this flap, a small triangular graft taken from the crest being wedged between the head and flap. The author uses specially designed extra-long, thin osteotomes in making the iliac flap (Figs. 2-A and 2-B). Internal fixation is secured by a bone plate, which is easy to shape with Jewett bending irons. The bone plate will exert a constant downward thrust on the iliac flap and will also protect it from fracture. The wound is closed with interrupted cotton sutures and a bilateral spica cast is applied as far as the toes on the involved side.

FIG. 4-A

FIG. 4-B

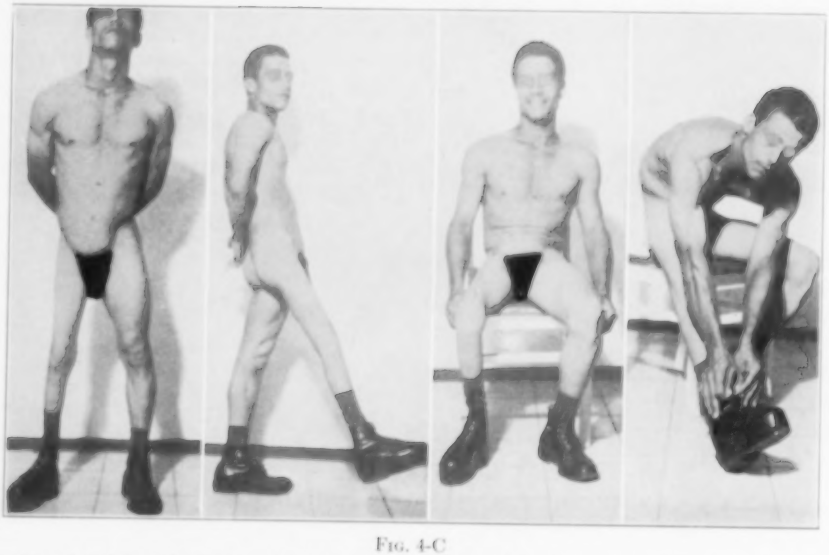

FIG. 4-C

Figs. 4-A, 4-B, and 4-C: Case 2. F. G., a patient with paralytic dislocation of the right hip (poliomyelitis) three years and seven months after surgery. He is asymptomatic and works standing up eight hours a day. A Lambrinudi procedure has been performed on the right foot.

## RESULTS

The results in this series of patients have been most gratifying (Figs. 3-A through 5-C). The arthrodesis relieved pain, achieved stability, and reduced the limp far more than would have been possible by any of the other standard procedures. Furthermore, the time of immobilization was reduced considerably, the paralytic patients being ambulatory at the end of one month and the arthritic patients, at the end of two months. Both groups wore single walking spicas for two months.

FIG. 5-A

FIG. 5-B

FIG. 5-C

Figs. 5-A, 5-B, and 5-C: Case 3. E. G., a patient with osteo-arthritis (malum coxae senilis) four years after surgery. Her hip is asymptomatic, but she complains of slight pain in her lower back.

Evidence of trabeculation extending continuously across the joint with absence of a continuous joint line was observed in 95 per cent of the group. The length of time that elapsed before fusion occurred was three to eleven months in the paralytic patients and four to twenty-nine months in the arthritic patients.

The two results that we consider failures were due, we believe, to improper immobilization, Vitallium having been used in one instance and stainless steel in the other.

Two of the forty-one patients in this series were operated on less than a year ago and thus are not included in the evaluation. The first patient in the series has been followed for five and a half years.

SUMMARY

1. The internal fixation used incorporates the contact-compression factor, while the iliac graft used incorporates the biological factors of osteogenesis and osteoclasis.

2. While functional quadriceps femoris power is a distinct advantage, it does not seem to be a necessity. Adequate ligamentous stability of the knee is a prerequisite.

3. The foot and ankle should be stabilized.

4. The pseudarthrosis rate for the entire group was 5 per cent (two cases). The rate of infection was also 5 per cent (two cases). Back pain was present in all the arthritic group following arthrodesis (28 per cent of the series, eleven cases).

5. The most certain method of producing arthrodesis is intra-articular fusion combined with bone-grafting and metal fixation.

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# Stenosing Tenosynovitis of the Common Peroneal Tendon Sheath

## Report of Two Cases

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The disease process of painful stenosing tenosynovitis (also called stenosing tendovaginitis) occurs more frequently in the common sheath of the extensor pollicis brevis and abductor pollicis longus tendons at the wrist than in any other location. In this tendon sheath the condition is not rare. It is usually called de Quervain's disease, as de Quervain's account in 1895 is probably the first and certainly the classical description of the condition. Since that time several papers on this condition have appeared in the literature. In this paper we wish to report two instances in which stenosing tenosynovitis occurred in the sheath of the peroneal tendons.

This condition in the peroneal tendon sheath was reported by Hildebrand in 1907 and by Hackenbroch in 1927. Hackenbroch's two patients with this disease were both over forty years of age; the condition was related to trauma, and both patients presented palpable, tender thickenings below the edge of the lateral malleolus. Pain at this area was aggravated by both supination and pronation of the foot. At operation, he found dense fibrotic thickening of the inferior retinaculum at the site of the clinical thickening and there was constriction of the peroneal tendons beneath this. Permanent correction was obtained after operation. Microscopic examination of the excised portion of the peroneal sheath showed non-specific inflammatory changes which Hackenbroch further described as primarily sclerotic fibrillar tissue.

Jagerink in 1929 described a case of stenosing tenosynovitis involving the common sheath of the extensor carpi radialis longus and brevis and another case involving the tibialis anterior. In the latter case the exact location of the stenosis was not described although one is led to infer it was above the cruciate ligament at the ankle. In both of his cases, Jagerink found thickening of the tendon sheath with narrowing and constriction of the tendon.

Palmborg, in reviewing the literature, found case reports of this disease process involving the sheaths of all the dorsal tunnels at the wrist except the sixth tunnel housing the tendon of the extensor carpi ulnaris. Finkelstein, previously, had included a case involving the extensor carpi ulnaris among his descriptions of stenosing tenosynovitis. Thus, all six of the dorsal tunnels have been implicated in this process. That the flexor tendons are not exempt is indicated by a case involving the flexor pollicis longus reported by Finkelstein. Finkelstein cited separate reports of thumb-flexor involvement by Nussbaum and Hauck, respectively. He also cited a case, reported by Vischer, involving the sheath of the flexor sublimis tendon of the fourth finger. Additional sites implicated in this disease process are the peronaeus longus tendon near its insertion into the base of the first metatarsal [1], anomalous extensor of the thumb [2], and an accessory tendon sheath over the radial styloid [3]. In addition, Lapidus and Fenton placed trigger-finger in this same category. In this, they are supported by Troell, who presumed that stenosing tendovaginitis and cases of snapping-finger are closely related to each other with respect to etiology, genesis, and pathological anatomy.

Jagerink believed that stenosing tenosynovitis may be entirely the result of continued or prolonged irritation on a mechanical basis. Therefore, he felt one should expect this process to develop in any tendon sheath in which the tendon bends or works in an angular direction with the expected increased irritation at such locations.

There are a few reports in the American literature of stenosing tenosynovitis at the foot or ankle. That such a condition can exist here was mentioned by Lapidus and Fenton and a brief description of this process occurring at the ankle has been presented by Lapidus and Seidenstein. The latter reported three cases of non-specific tenosynovitis about the ankle, but these were not stenosing and did not involve the peroneal tendons.

More recently, Burman cited cases of stenosing tenosynovitis involving the tibialis anterior, the tibialis posterior at the ankle, and the extensor digitorum longus. In discussing the painful peroneal tubercle, Burman also described eight cases of tendovaginitis of the peroneal sheath at the level of the peroneal tubercle (trochlear process) of the calcaneus. Operation was performed in five, and two of these showed stenosing tenosynovitis.

In our cases, herein reported, the pathological changes were proximal to the peroneal tubercle in the common-sheath area behind the lateral malleolus.

Descriptions of the microscopic picture in stenosing tenosynovitis are meager. Most authors speak of a fibrous thickening of the tendon sheath. Finkelstein, in 1930, gave an extensive review of the literature. He presented theories of etiology, reproduced the disease factors in rabbits, and reported twenty-four of his own cases. In Finkelstein's cases, the macroscopic findings ranged from mild involvement with slight changes, the tendon sheath being approximately twice the normal thickness without inflammatory changes, to marked thickening with inflammation. He pointed out that the tendons are thinned at the site of constriction and enlarged somewhat beyond the constricted area with decrease of freely gliding movement. In the severe cases, he found that "the sheath may be very greatly thickened, being three or four times thicker than average, densely fibrous, or even of cartilaginous consistency, and the sheath is brownish or reddish in color". He further noted loss of normal pearly luster and occasionally adhesions between the tendons and the sheath. Beyond the portion of constriction, the tendons are often bulbous. The microscopic findings in Finkelstein's cases were as follows: "In *mild* cases

the synovial membrane is thickened, except at the point of constriction, where it is thin or entirely absent. The loose connective-tissue layer is considerably thickened and vascularized; the ligamentous layer is slightly thickened but not vascularized. Only rarely is there a line of demarcation between the loose connective-tissue layer and the ligamentous layer. In *severe* cases the synovial layer is completely destroyed, the loose connective-tissue layer is compressed and thinned out, while the ligamentous layer is markedly thickened and undergoes hyaline and cartilaginous transformation. There is also marked thickening of walls of blood vessels, and cellular infiltration of the tissues, numerous lymphocytes being present. Between these two types there are many gradations."

In 1933 Huber reported detailed microscopic findings in nine cases of what he regarded as typical stenosing tendovaginitis. He described an inner, middle, and outer portion of the tendon sheath. The external sheath consisted of fibrous tissue moderately rich in cells. The fibrous tissue was dense and hyaline or loose with irregularly interwoven fibers. In some places there was fat tissue and, occasionally, nerve tissue. The middle layer, which is usually one to 1.5 millimeters thick, is most sharply demarcated from the inner layer. It contains fibrous tissue, the fibers running parallel to the surface, and shows some lymphocytic infiltration. Capillaries course from the inner to the middle layer and back again, apparently terminating in the inner layer. The inner zone showed fibrocartilage and a net of elastic fibers arranged in circular fashion. Inflammatory changes consisting of lymphocytic infiltrations were found in the external zone. This report is at variance with other reports in so far as the site of inflammation is concerned.

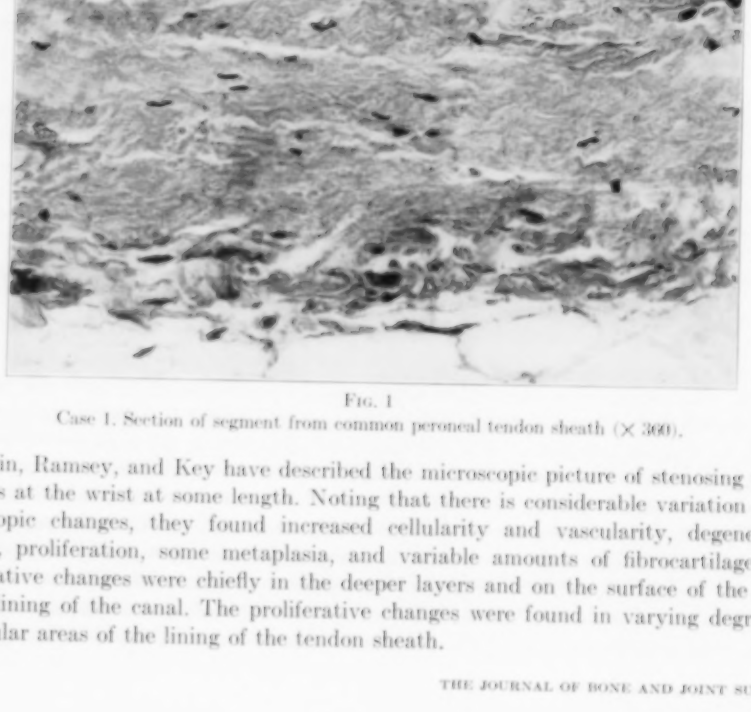

FIG. 1

Case 1. Section of segment from common peroneal tendon sheath (× 360).

Stein, Ramsey, and Key have described the microscopic picture of stenosing tendovaginitis at the wrist at some length. Noting that there is considerable variation in the microscopic changes, they found increased cellularity and vascularity, degenerative changes, proliferation, some metaplasia, and variable amounts of fibrocartilage. The degenerative changes were chiefly in the deeper layers and on the surface of the dense fibrous lining of the canal. The proliferative changes were found in varying degrees in the cellular areas of the lining of the tendon sheath.

Case 1. A white male sergeant, twenty-three years old, was admitted to the Orthopaedic Service of Colonel A. W. Spittler at Walter Reed Army Hospital on April 25, 1951. He complained of pain in the lateral aspect of the right ankle. His symptoms had begun suddenly while he was double-time marching in place on October 1, 1950, and had persisted in spite of repeated courses of conservative treatment, such as physiotherapy and plaster immobilization of the foot and ankle.

The physical examination was essentially negative except for moderate swelling over and below the right lateral malleolus and tenderness beneath its lower edge. There was a 10-degree limitation of dorsiflexion of the right ankle. Routine blood and urine examinations were within normal limits. Roentgenograms of the right ankle showed an old ununited minimal chip fracture of the very tip of the lateral malleolus.

On May 4, 1951, under sodium pentothal anaesthesia, exploration of the lateral malleolus and the common peroneal tendon sheath beneath the malleolus was carried out through an inferiorly curved lateral incision. A small ununited chip of bone, approximately one by 0.5 by 0.4 centimeters, found 0.6 centimeter below the distal tip of the lateral malleolus was removed. Posteriorly and inferiorly to the lateral malleolus, the common peroneal tendon sheath was exposed and was found to be greatly thickened, constricting the enclosed tendons for a length of approximately 2.5 centimeters. The sheath was approximately twice the expected thickness, with loss of luster and of inner-surface moisture. There was no single point of constriction but instead quite uniform compression of the tendon throughout the length of the exposed portion of the sheath. The tendon itself had lost its normal moist and lustrous appearance and was slightly narrower throughout the area of constriction. There was no distinct bulbous enlargement. There was no evidence of calcification of the sheath or tendons. A linear segment of the thickened sheath 0.3 centimeter wide was excised laterally to allow free movement of the peroneal tendons. Postoperative healing was uneventful. With physiotherapy, the patient regained a full range of motion of the right ankle with good stability. He was returned to duty on August 17, 1951.

It would be convenient to ascribe the cause of the tenosynovitis to the chip of bone; however, although the chip of bone was located in the general vicinity of the peroneal sheath, it was superficial or lateral to the stenosed sheath. It did not seem possible that tension or pressure forces on the tendon would result from this chip and it is therefore doubtful that the bone chip was a significant factor in development of the stenosing tenosynovitis in this case.

Microscopic examination of the tendon-sheath segment disclosed only two layers. The outer layer was composed largely of dense fibrous tissue with moderate oedema and very few blood vessels. The inner layer was composed of less dense fibrous tissue with many areas of interspersed fat and many more blood vessels. In the inner layer, numerous lymphocytes with a few plasma cells, occasional eosinophilic polymorphonuclear leukocytes, and occasional macrophages were found. In one area, at approximately the middle of the specimen, there was a moderate, thin deposit of fibrin on the lining side of the sheath. Similar infiltrates were clustered about the vessels near the perimeters of the inner and outer layers. A deposit of hemosiderin was seen at the lining edge in one area, probably representing a less severe reaction or an earlier reactive phase.

Microscopic examination of the bone fragment showed it to be viable. The small area of attached fibrous tissue removed with the bone showed no surrounding inflammation which further led us to believe that the chip in itself was not a factor in the development of the condition in this case.

Case 2. A white male, thirty-five years old, was admitted to the Missouri Baptist Hospital in St. Louis, Missouri, on June 19, 1952. Six months previously, a painful lump had developed in the left foot on the outer aspect of the tarsus under the lateral malleolus. There was no history of injury. The lump enlarged, becoming more painful on activity and improving with rest. He had first been seen three months previously in the office and deep x-ray therapy over the lump was given, without relief of symptoms.

Physical examination showed a mild pes cavus with moderate claw-toe deformity. There were callosities under the second and fifth metatarsal heads on the left. There was a small, very tender, enlarged area on the lateral side of the left tarsus under the lateral malleolus. Inversion of the foot was painful. The small tumor felt like a tight cyst or ganglion. Complete blood count, urinalysis, and serological studies gave findings within normal limits. Preoperative diagnosis was a ganglion, and excision was advised.

On June 20, 1952, the area of the peroneal tendons was explored through a 3.8-centimeter incision over the swelling with the operative field made bloodless by a tourniquet. It was found that the tumor was caused by a marked thickening of the sheath enclosing the two peroneal tendons and that this thickening extended for a distance of about two centimeters. A section of the sheath was excised. The tendons were not disturbed,

FIG. 2-A

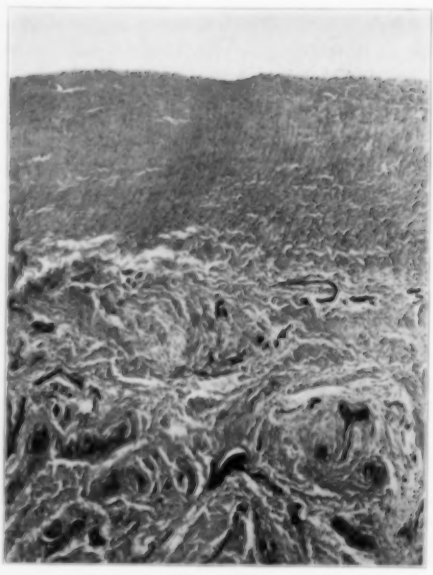

FIG. 2-B

Fig. 2-A: Case 2. The photomicrograph (× 61) shows at the top the lining of the tendon sheath. The sheath is flattened and smooth at the tendon surface. Below the lining layer of the sheath is the center layer with an area of small, thick-walled vessels.

Fig. 2-B: Photomicrograph (× 50) showing two layers of the tendon sheath. At the top is the dense layer of orderly arranged fibrous connective tissue on the surface; and on the bottom, the irregular vascular layer in the central portion of the thick sheath.

as they appeared normal. The sheath was left open and the deep fascia was closed with interrupted catgut sutures and the skin, with silk. A pressure dressing was applied and the tourniquet was removed at the end of the procedure.

The patient made an uneventful recovery. He returned to work in three weeks relieved of his symptoms.

On microscopic section, the sheath of the peroneal tendon was found to be composed mainly of mature fibroblasts arranged in layers. The deeper layer of the sheath was relatively avascular and composed of collagen fibers, arranged in an orderly and well organized fashion. The cells on the surface of this layer were flattened somewhat.

The central layer was composed of whorls of mature connective tissue, some areolar and some dense, which was traversed by numerous thick-walled vessels of varying sizes. Although no lumen was seen in some of these, they were thought to be vessels. No areas of cell infiltration or giant cells were noted. Smooth, regularly arranged, dense fibrous connective tissue composed the outer layer.

## SUMMARY

While stenosing tenosynovitis over the radial styloid (de Quervain's disease) is generally well recognized, the dearth of literature on the same condition in the common peroneal tendon sheath indicates that the latter is either rare or not commonly recognized.

As in de Quervain's disease at the wrist, the gross thickening of the common peroneal tendon sheath and constriction of the tendon correspond to the area of pain and of local tenderness beneath the lateral malleolus. Relief of symptoms can be obtained by partial or total excision of the thickened tendon sheath.

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# Hip Dislocation in Cerebral Palsy

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Gherlinzoni reported twenty-three patients with dislocated hips among 500 children with cerebral palsy (4.6 per cent), and he quoted several authors (Gaugele, Weber, Künne, and Strata) who had previously reported hip dislocations in patients with cerebral palsy. Mathews, Jones, and Sperling, in a study of 1,243 cerebral palsy patients, reported thirty-two children (2.6 per cent) with either subluxation or dislocation of the hip. Jones studied twenty-two paralytic dislocations of the hip in fourteen patients; nine of his patients had spastic cerebral palsy.

The purpose of this paper is to present a study of hip dislocation and subluxation in cerebral palsy, stressing the importance of prophylaxis, early diagnosis, and treatment. The paper is based on a study of 590 cases of cerebral palsy seen at the Carrie Tingley Hospital for Crippled Children, Truth or Consequences, New Mexico, during the past eight years.

## ANALYSIS AND DISCUSSION OF CLINICAL MATERIAL

On clinical examination, fifty-six of the 590 patients (9.5 per cent) were suspected of having hip disorders, and roentgenograms were made. These consisted of anteroposterior views of the pelvis, the lower extremities held in neutral position, and true lateral views of the hip when possible. Anteversion studies were not done until two years ago, when we started using Shands'[2] method and positioning apparatus.

TABLE I

INCIDENCE OF HIP DISLOCATION AND SUBLUXATION IN CEREBRAL PALSY

| Author | Total No. of Patients With Cerebral Palsy | No. of Patients with Involved Hips | Patients with Dislocation (*Per cent*) | Patients with Subluxation (*Per cent*) |
|---|---|---|---|---|
| Gherlinzoni | 500 | 23(4.6%) | 3.6 | 1.0 |
| Mathews | 1243 | 32(2.6%) | 1.1 | 1.5 |
| Tachdjian and Minear | 590 | 25(4.24%) | 1.52 | 2.72 |

### *Coxa Valga*

Review of these roentgenograms disclosed marked coxa valga in all fifty-six patients. The true cervicofemoral angle is difficult to determine from roentgenograms, because any rotation of the femoral shaft may simulate a straightening of the angle to as much as 180 degrees. The true cervicofemoral angle is the smallest angle which can be demonstrated roentgenographically by rotation of the femur[15].

Roentgenograms of forty-five patients disclosed an average coxa valga of 164 degrees (142 degrees minimum and 178 degrees maximum). Roentgenograms of the remaining

eleven patients were not satisfactory for determining the angle made by the shaft and neck of the femur.

*Incidence of Hip Dislocation or Subluxation*

Twenty-five of the fifty-six patients had either subluxation or dislocation of the hip. These twenty-five patients with cerebral palsy and involved hips were chosen for the study. Eight patients were affected bilaterally, and seventeen unilaterally (eight on the right side and nine on the left side). The total number of affected hips was thirty-three, of which thirteen were dislocated and twenty subluxated.

Subjective factors enter into the distinction between subluxation and dislocation of the hip. Wiberg defined dislocation as the condition when the femoral head is completely outside the acetabular socket and has no contact with it; that is, it is outside the limbus cartilage. When there is contact between the head and the acetabular socket, he defined the condition as subluxation.

In Table I the authors' incidence is shown compared with the incidence reported by other authors.

TABLE II

INCIDENCE OF HIP DISLOCATION IN TWENTY-FIVE PATIENTS WITH VARIOUS TYPES OF CEREBRAL PALSY

| Type of Cerebral Palsy | No. of Patients with Dislocated or Subluxated Hips |
|---|---|
| Spastic quadriplegia | 13 |
| Spastic triplegia | 1 |
| Spastic paraplegia | 4 |
| Spastic hemiplegia | 4 |
| Mixed: athetoid and spastic quadriplegia | 1 |
| Athetoid, flexion-extension type | 1 |
| Unclassified | 1 |

TABLE III

| | Degree of Coxa Valga | | | Acetabular Index | | CE Angle (Wiberg) |
|---|---|---|---|---|---|---|
| | Average (*Degrees*) | Minimum (*Degrees*) | Maximum (*Degrees*) | Average (*Degrees*) | No. of Hips Above 25 Degrees | Average (*Degrees*) |
| Dislocated or subluxated hips | 170 | 160 | 178 | 24.4 | 7 | 14 |
| Normal hips | 160 | 145 | 170 | 16.3 | None | 24 |

*Age and Sex Incidence*

Among the twenty-five patients there were thirteen males and twelve females. At the time of diagnosis, their ages ranged from two to ten years, with one eighteen-year-old patient. The average age was 5.9 years.

*Relation to Weight-Bearing*

Ability to bear weight was evenly divided among the group. Thirteen were able to bear weight and twelve were not.

*Relation to Type of Cerebral Palsy*

Table II shows the incidence of hip dislocation in various types of cerebral palsy in this group of twenty-five patients. Note that twenty-three out of the twenty-five (92 per cent) had spasticity. In the group presented by Gherlinzoni, all of the patients with dislocated hips had spastic cerebral palsy, and in Mathews' group, 78 per cent had spastic cerebral palsy.

Of the 590 patients with cerebral palsy seen at the Carrie Tingley Hospital, 69 per cent were spastic, 19 per cent were athetoid, and other types of cerebral palsy comprised 12 per cent.

TABLE IV

COMPOSITE MUSCLE TEST OF INVOLVED SIDE

| Muscle | Spastic Group | | Mixed Group | |
|---|---|---|---|---|
| | Physiological Status | Motor Power | Physiological Status | Motor Power |
| Glutaeus maximus | In | N | In | N |
| Hip abductors | OC | T, or O | OC | T, or O |
| Hip adductors | S | N | In | N |
| Internal rotators | S | N | In | N |
| External rotators | OC | T, or O | In | P, or T |
| Hip flexors | S | N | In | N |
| Quadriceps | In | N | In | N |
| Hamstrings | S | N | In | N |

*Acetabular Index, CE Angle (Wiberg), and Coxa Valga*

The degree of coxa valga could be determined in twenty of the twenty-five patients. Table III gives the degree of coxa valga in the twenty patients, and the acetabular index and the CE angle (Wiberg) in the twenty-five patients. Six patients with seven affected hips had an acetabular index above 25 degrees.

*Dynamic Imbalance of Subluxated or Dislocated Hips*

All patients with cerebral palsy and hip disorders were given repeated composite muscle tests. In Table IV the dynamic imbalance of the muscles about the involved hip is shown in the two groups of cerebral palsy patients, one a spastic group and the other composed of patients with mixed types of cerebral palsy. Note particularly that in both groups the main dynamic imbalance is between two sets of muscles; hip adductors as opposed to hip abductors, and internal rotators as opposed to external rotators. Both hip adductor and internal rotator muscles are graded as spastic and normal motor power (*S, N*) in the spastic group and innervation normal and normal motor power (*In, N*) in the mixed group; whereas the hip abductor and external rotator muscles are graded as cerebral zero (*OC*) with trace or zero motor power (*T, O*) in the spastic group, and normal innervation and poor motor power (*In, P*) in the mixed group.

The following points should be considered in the muscle examination of a child with cerebral palsy:

1. One should distinguish the difference between voluntary resistance and stretch reflex. In the stretch reflex, the muscle contracts vigorously when suddenly elongated. It is an automatic reflex and will occur whenever the muscle is stretched. The muscle must be stretched repeatedly in order to rule out voluntary resistance on the part of the patient imitating the stretch reflex.

2. One should distinguish between tension athetosis and spasticity. Tension athetosis is produced by the intentional effort of the athetoid patient to prevent any undesired motion of the athetoid extremity. By shaking the extremity the voluntary tension can be shaken loose. The spastic limb cannot be shaken loose because the stretch reflex is automatic; the limb will resist and maintain the spastic position.

3. The patient has no voluntary control over the cerebral zero (*OC*) muscle. However, an *OC* muscle can be trained to reflex contraction by the voluntary contraction of related muscles (automatic reflex). For example, a cerebral zero tibialis anterior muscle may be made to contract by the voluntary contraction against resistance of the hip flexors on the same side.

TABLE V

PHYSIOLOGICAL STATUS VARIATIONS IN MOTOR STRENGTH OF MUSCLES IN CEREBRAL PALSY PATIENTS

| Physiological | Motor Strength |
|---|---|
| Innervation normal (In) | P to N |
| Spastic (S) | P to N |
| Hypotonic (H) | O to G |
| Cerebral zero (OC) | O to G |

In charting these muscles, motor power and physiological status should both be designated. Motor strength may be graded by the standard accepted by the National Foundation for Infantile Paralysis and the same abbreviations used: zero, *O*; trace, *T*; poor, *P*; fair, *F*; good, *G*; and normal, *N*. For muscle physiological status notations we use the following abbreviations: *S* for spastic (stretch reflex), *H* for hypotonic, *OC* for cerebral zero, *In* for innervation normal.

Table V shows various possible physiological and motor power combinations of muscles in patients with cerebral palsy.

## TREATMENT AND RESULTS

Cerebral palsy comprises those symptom complexes caused by a non-progressive brain lesion (or lesions)[11]. It incorporates motor, sensory, and mental handicaps in the individual in varying degrees.

In studying the cerebral palsy patient there are four important aspects to consider. In order of their importance they are: (1) the extent of communication, or speech; (2) the amount of self-help the patient is capable of, or his use of arms and hands; (3) the degree of locomotion possible, or use of the legs; and (4) the patient's general appearance. In this study we are considering hip dislocation as a handicap to locomotion.

One should be sure to evaluate the patient as a whole before outlining treatment. Since many patients are poor operative risks, prophylaxis, early diagnosis and treatment are very important to forestall major surgical procedures.

In our series, we used both conservative and surgical treatment. Conservative treatment and prophylaxis consisted in (1) the use of the abduction-internal rotation splint, and of the Frejka pillow for infants; (2) passive stretching of the hip adductors and internal rotators; that is, stretching them gradually so as not to initiate the stretch reflex; and (3) the establishment of an automatic reflex to cerebral-zero hip abductors in an attempt to increase their motor strength and establish a dynamic balance.

Operative treatment consisted in three procedures: (1) adductor tenotomy, or obturator neurectomy, followed by closed reduction of the hip and splinting in abduction; (2) open reduction and shelf operation[6, 18]; and (3) osteotomy to correct coxa valga [8] or derotational osteotomy, if marked anteversion is present, or both.

Table VI shows treatment of the group and results. Eight patients were treated conservatively; five of these had mild subluxation and three were poor operative risks. Seventeen patients were treated surgically.

The average postoperative follow-up was three years and two months; minimum follow-up was six months and maximum was seven years and six months. Clinical evaluation of functional results was very difficult because of mental retardation and other handicaps in most of the patients.

Anteversion studies should be done in all patients with hip dislocation in cerebral palsy. If marked anteversion is present (we take 40 degrees as the upper limit, basing it on our anteversion studies in congenital hip dislocations), derotational osteotomy of the femur should be performed.

TABLE VI

TREATMENT AND RESULTS

| Group I: Conservative Treatment | | | | |
|---|---|---|---|---|
| Subgroups | Total No. of Patients | Result: Good | Fair | Poor |
| Patients with very poor prognosis, markedly retarded mentally with convulsive seizures | 3 | | | 3 |
| Patients with mild to moderate subluxation of hip | 5 | 3 | 1 | 1 |

| Group II: Operative Treatment | | | | | | |
|---|---|---|---|---|---|---|
| Subgroups | Total No. of Patients | No. of Hips Dislocated | No. of Hips Subluxated | Result: Good | Fair | Poor |
| Obturator neurectomy or adductor tenotomy and closed reduction | 14 | 8 | 12 | 12 | 2 | |
| Open reduction and shelf operation | 2 | 2 | | 1 | 1 | |
| Open reduction, shelf operation, and derotational osteotomy | 1 | 1 | | 1 | | |

## PATHOGENESIS OF HIP DISLOCATION IN CEREBRAL PALSY

### *Mechanics of the Normal Hip*

With weight-bearing, the hip joint acts on a lever principle [7, 12]. The long arm of the lever supports the body weight; the short arm is depressed by the abductors of the hip, with the hip joint acting as the fulcrum of the lever. The weight of the body is exceeded by the force of the abductor muscles and the tension of the iliotibial band by a ratio of 1:1.4 to 1:1.9. The minimum static load on the head of the femur is approximately 2.4 to 2.6 times the body weight, and this static force is not altered by changes in the level of the pelvis on the non-weight-bearing side [7]. The direction of this force follows the medial trabeculae of the femoral neck. The proximal femoral epiphyseal line and medial trabeculae are always at right angles to each other; this is clearly shown in roentgenograms of the upper end of the femur in various age groups. Thus, the only force to which the epiphyseal cartilage is subjected normally is a compressional one. As the reacting force in the femur follows the medial trabeculae, there is minimal sheer on the epiphyseal cartilage, or none at all.

With growth, the femoral neck lengthens, and there is an increase in the angle of pull of the abductor muscles; the epiphyseal cartilage plate rotates so as to be perpendicular to the equilibrant force in the femoral neck.

*Pathomechanics of Coxa Valga and Hip Dislocation in Cerebral Palsy*

The muscle study in our patients showed a dynamic imbalance between the hip abductors and adductors, either a paralysis of the abductors or spasticity of the adductors, or both. Brandes reported development of coxa valga in a patient whose greater trochanter had been removed because of tuberculosis; there was loss of tone in the abductors. Similar cases have been noted since.

The main function of these two muscle groups is the shifting of the pelvis and trunk from the rest position to the side of the weight-bearing limb, during walking [17]. For example, if the weight-bearing limb is the right one, the following movements take place as the left limb starts to swing forward: (1) the right abductors contract and incline the pelvis to the right side; (2) at the same time, the right adductors contract and act as a brake for this movement, and are prepared by (3) further contraction to initiate the swing of the pelvis to the left side. When the left foot reaches the ground, the left limb becomes the weight-bearer.

TABLE VII

CLASSIFICATION OF RESULTS

| Result | Walking | Limp (Glutaeus Medius) | Roentgenographic |
|---|---|---|---|
| Good | With or without braces | None or minimal | Reduced |
| Fair | With braces | Moderate | Minimal subluxation |
| Poor | Walking, none; stand with support of table | Marked | Still subluxated or dislocated |

This alternating pelvic tilt and the normal hip mechanism is disturbed in abductor weakness. There is loss of equilibrium. To prevent the pelvis from rotating toward the non-weight-bearing side, the individual shifts his center of gravity over the affected hip by bending to that side. The resultant force, acting through the hip, becomes more nearly vertical. The equilibrant, or reacting, forces in the femoral neck likewise shift toward the vertical; the epiphyseal cartilaginous plate, remaining at right angles to these forces, continues to be relatively horizontal, and coxa valga results. With increased coxa valga due to this abnormal functioning of the femoral head and acetabular socket, subluxation and dislocation of the hip eventually develop. The degree of coxa valga is in proportion to the loss of muscle power.

CONGENITAL DISLOCATION OF THE HIP IN PATIENTS WITH CEREBRAL PALSY

In our series, the acetabular index of six patients with seven affected hips was above twenty-five degrees. Prior to coming to us, roentgenographic examinations were made of three of these six patients which disclosed coxa valga but showed that the femoral heads were within the acetabular sockets. Definitely, then, the hips of these three patients were not congenitally dislocated.

From the point of view of the statistician, it is possible that the hips of the remaining three patients were congenitally dislocated. Ettore classified dislocation of the hip in cerebral palsy as follows: (1) due only to spasticity; (2) due partly to spasticity and partly to congenital dysplasia of the hip; (3) congenital. The practical value of Ettore's classification is limited because the dynamic imbalance of the hip muscles resulting from congenital hip dysplasia and subluxation is the same principle which is at work in children with cerebral palsy, and which produces eventual non-congenital dislocation.

## SUMMARY AND CONCLUSIONS

1. In a series of 590 cerebral palsy patients, twenty-five (4.24 per cent) showed evidence of dislocation or subluxation of the hip. Twenty-three of these had spastic cerebral palsy.

2. The dynamic imbalance of the hip in these patients is shown by muscle study. The pathomechanics of coxa valga and of hip dislocation in cerebral palsy are discussed.

3. The treatment of our patients and the end results are presented, stressing the importance of prophylactic tenotomy of the spastic hip adductors and of strengthening the motor power of the cerebral-zero hip abductors by automatic reflex.

4. Dislocation of the hip in cerebral palsy is preventable. If we are aware of the probabilities and understand the pathomechanics, we will regard every child with spastic lower limbs as having potential subluxation or dislocation of the hip.

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# An Etiological Factor in Tear of the Distal Tendon of the Biceps Brachii

## Report of Two Cases

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The authors became interested in rupture of the distal tendon of the biceps brachii as a result of encountering an unusual case in their clinical practice. This case illustrates an etiological factor which the authors had not previously encountered in their personal experience and of which they can find no mention in the literature.

An extensive literature concerning tendon rupture is to be found in American and French journals. Much has been written concerning rupture of the long head of the biceps brachii, but only a few articles have appeared describing rupture of the distal tendon.

Rupture of the distal tendon was first recorded by Acquaviva in 1898. Dobbie, in 1941, found that twenty-four cases had been reported in the literature between 1898 and 1939. He described one new case of his own and reported fifty additional cases which he had been able to collect by circularizing 490 physicians throughout the country. Lee and Kron and Satinsky added twenty cases to the literature, making a grand total of ninety-five cases published in the literature by 1955.

The authors' primary interest in reviewing the literature was to search for possible primary etiological factors leading to rupture of the biceps brachii. Dobbie did not describe local etiological factors. Delarue and Denoix stated that tendon rupture is the result of violent muscular contraction superimposed upon pre-existing degenerative changes in the tendon structure. Waugh and associates, in an article on tendon rupture, concurred with this opinion and alluded to Bouchers' concept that rupture of the long head may be due to the wear and tear which is the result of the presence of osteophytes along the bicipital groove. Gilcreest, in a classic article on rupture of the long head of the biceps, mentioned Ewald's concept that tendon rupture is always the result of pre-existing local disease. Meyer, cited by the same author, felt that rupture of tendons is due to abnormal friction. Dobbie mentioned that the various surgeons contacted in his survey had commented upon the bulbous and frayed end of the avulsed or ruptured tendon but did not discuss any specific cause. Sénèque and Berthe believed that avulsion of the distal tendon of the biceps is always purely traumatic in origin, being a tearing and not a true rupture. Debeyre agreed with this opinion and reported that he had found no roentgenographic evidence of local pathological change about the radial tuberosity. Edelmann, however, postulated that pre-existing pathological changes may explain the occurrence of tearing subsequent to minimal trauma. Chevallier stated that the avulsion takes place in two stages: in the first stage, tearing occurs as a result of pre-existing pathological changes; in the second, the rupture is completed by muscle contraction which causes tearing of the lacertus fibrosus. The latter stage presents the clinical picture of acute trauma.

### CASE REPORTS

Case 1. A. M., a white male, fifty-two years of age, was admitted with a complaint of painful swelling in the right antecubital fossa of four weeks' duration. The pain was aggravated by repeated use of the elbow at work. It was most marked when the elbow was supinated following full pronation, and this motion was accompanied by a creaking sensation. There was no history of previous illness or trauma. The patient had been employed for twenty years as a chipper in a local foundry, a job which entails the constant use of a small air hammer. Examination of the right elbow revealed a mass, two centimeters in diameter, lying in the

FIG. 1-A

FIG. 1-B

Figs. 1-A and 1-B: Case 1. Anteroposterior and lateral roentgenograms of the right elbow (these roentgenograms are reversed). The radial tuberosity is moderately enlarged and its margin is irregular, as indicated by the arrows.

antecubital fossa just lateral to the biceps tendon. The mass was firm, cystic, tender to palpation, and fixed to the deep tissues. The elbow had a full range of motion, and good power was demonstrated by manual testing. Extremes of supination, pronation, and extension caused pain, but the subjective complaint of grating could not be reproduced. Roentgenograms of the elbow revealed slight irregularity and enlargement of the radial tuberosity (Figs. 1-A and 1-B). The differential blood count, urine, sedimentation rate, and blood chemistry were all within normal limits.

At operation, the mass was approached through an L-shaped anterior incision, under tourniquet control. The mass was found lying under the deep fascia just distal and lateral to the biceps tendon. The deep fascia was incised and a ganglion-like tumor was discovered firmly adherent to the biceps tendon, extending distally to the insertion of the tendon. The radial recurrent vessels were divided in order to facilitate exposure of the radial neck and tuberosity, the technique of Henry being used. Several tag-like, bulbous thickenings of the biceps tendon were observed near its insertion. The tumor was opened and found to contain a thick synovial-like fluid; its inner surface had a villous appearance with marked

FIG. 2

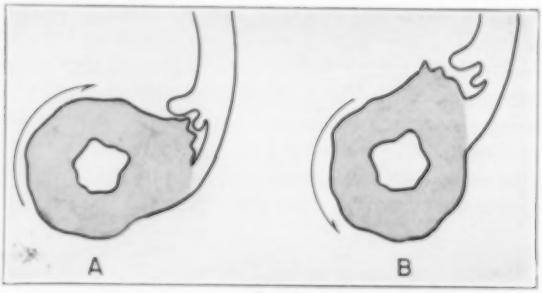


FIG. 3

Fig. 2: This line drawing demonstrates the appearance of the lesion at the time of surgery. The dotted line represents the enlarged bicipital bursa.

Fig. 3: A cross section of the area of the arm indicated by the straight line in Fig. 2. When the arm is pronated (*A*), the sharp margin of the tuberosity impinges on the tendon; when the arm is supinated (*B*), the tendon is pulled free.

FIG. 4-A

Figs. 4-A and 4-B: Case 2. Anteroposterior, lateral, and oblique roentgenograms of the left elbow.

FIG. 4-B

erythema. The mass was dissected from the surrounding tissues and was found to be contiguous with the bicipital bursa lying between the distal biceps tendon and the radial tuberosity. The insertion of the biceps was then fully visualized, revealing that the tendon was frayed through approximately one-half of its thickness, with bulbous tags lying on its lateral aspect (Fig. 2). These findings indicated that the lateral surface of the tendon had been severely eroded by some factor. The radial tuberosity was explored, and a knife-like hypertrophic lip was found on its anterior margin. This bony lip impinged upon the lateral aspect of the biceps tendon when the forearm was placed in pronation and then eroded the tendon as the arm was supinated (Fig. 3). The hypertrophic lipping was removed by means of a small osteotome, and the loose frayed tendon was sutured to the underlying brachialis. The biopsy showed: (a) chronic tenosynovitis with organized fibrin and retrogressive changes in the dense connective tissue, but no neoplasm or specific granuloma; (b) fatty marrow in the cortical and cancellous bone, patchy fibrosis of the marrow spaces, focal retrogressive changes in the articular cartilage; (c) chronic synovitis.

A second case displaying the same basic etiological factors was observed by one of the authors (W. M. D.).

CASE 2. The patient, Mr. A. C., a forty-five-year-old white man employed as a grave digger, had had no previous difficulty with his elbow. He entered the Akron City Hospital emergency ward complaining of having "torn a leader" in his left elbow. This injury had occurred when a grave vault had slipped while he was supporting one end, his elbows being flexed to 80 degrees and his forearms being fully supinated.

Examination revealed marked tenderness with diffuse swelling and subcutaneous hemorrhage in the left antecubital fossa. The power of supination and flexion in the left elbow was impaired as compared to that in the opposite elbow. Motion of the elbow, either active or passive, was accompanied by moderate pain in the antecubital area.

Anteroposterior, lateral, and oblique roentgenograms of the left elbow revealed an irregularity of the bicipital tuberosity with some enlargement (Figs. 4-A and 4-B). No other pathological changes were noted.

This patient was taken to surgery, and the left antecubital region was exposed under tourniquet control, as had been done in the first case. The distal biceps tendon had been completely avulsed from the radial tuberosity and was lying coiled upon itself distal to the lacertus fibrosus. Inspection of the tendon revealed evidence of chronic erosion involving the lateral two-thirds, with yellow, bulbous, rounded tags. The medial one-third was obviously freshly torn from its bony attachment. The radial tuberosity was observed to be markedly irregular with a sharp, knife-like, irregular anterior margin. The condition was thought to be identical with that in the first case except that complete rupture of the tendon had occurred.

The surgical repair consisted in resection of the damaged end of the tendon and suture of the remaining portion to the underlying brachialis tendon. The postoperative course was uneventful, and the patient returned to full employment; when last seen, his only complaint was minimal weakness of the left elbow when the arm was supinated.

## DISCUSSION

In these cases degenerative changes were present in the tendon, and hypertrophic lipping had developed along the anterior margin of the area of the radial tuberosity in which the biceps tendon inserts. A minor tear developed in the tendon as a result of friction along the anterior margin, following which the rent was extended as the tendon was pulled across this knife-like edge during pronation and supination.

It is the opinion of the authors that the knife-like margin of the bicipital tuberosity was the basic etiological factor which produced erosion of the biceps tendon in both these cases. In the first case, ultimate rupture would undoubtedly have occurred if repair had not been done. Furthermore, if the usual method of treatment had been followed (simple suture of the biceps insertion and the brachialis), exploration of the radial insertion would have been precluded and the basic pathological changes would, in all probability, have been overlooked. It is hoped that others will inspect the margins of the radial tuberosity in future cases to determine the prevalence of this finding.

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# The Repair of Knee Ligaments by Cutis-Graft Transplants

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The necessity for repair of knee ligaments by operation has been debated for a long time.

Campbell's Operative Orthopedics states: "The status of operative repair of the ligamentous structures of the knee would seem to be controversial. The results of these procedures, interpreted in the light of their efficiency in the military services, are conducive to an attitude of pessimism."

It was stated further in this text: "Neither the normal anatomy nor function of the original set of ligaments can be restored by surgical reconstruction. . . .

"One should recognize from the beginning that the newly reconstructed ligaments are capable of withstanding average activity, but are entirely inadequate, as a rule, for athletics and similar rigorous activities."

In 1950, O'Donoghue advocated immediate repair of the collateral and cruciate ligaments in acute injuries and reported twenty cases in which satisfactory results had been obtained. The lacerations had been repaired by simple suture.

TABLE I

| Number | Age and Sex | Ligaments Involved | Results | Follow-Up | Joint Instability | Occupation | Return to Original Work |
|---|---|---|---|---|---|---|---|
| 1 | 43 M | Fibular collateral | Fair | 7 mos. | Marked | Coal miner | Yes |
| 2 | 27 M | Tibial collateral | Excellent | 19 mos. | Marked | Coal miner | Yes |
| 3 | 24 M | Anterior cruciate | Excellent | 12 yrs. | Marked | Coal miner | Yes |
| 4 | 19 F | Fibular collateral | Good | 28 mos. | Extremely marked | Stenographer | Yes |
| | | Tibial collateral | Good | 25 mos. | Extremely marked | | |
| | 20 | Anterior cruciate | Good | 14 mos. | Extremely marked | | |
| 5 | 19 F | Fibular collateral | Fair | 25 mos. | Extremely marked | Housewife | Yes |

The most severe knee-ligament injuries take place as a result of dislocation of the knee. In these cases, however, the damage is recognized from the beginning. The ligaments are adequately protected, and satisfactory repair usually takes place. It is in the cases in which there is somewhat less trauma that permanent ligament relaxation may occur, due to failure to evaluate the damage properly. It is my opinion that the tibial collateral, the fibular collateral, the anterior cruciate, and, rarely, the posterior cruciate ligaments should be repaired by operation if their condition is chronically disabling. Relaxation of any one of these ligaments, if it is sufficient, can lead to disability so far as doing ordinary manual labor is concerned.

The usual methods of repairing the collateral and cruciate ligaments are well known and will not be discussed in this paper. Fascia lata has been the material ordinarily used for the repair. Tendons may also be used, and another possibility is to tighten the capsule, as is done in Mauck's technique for the repair of the tibial collateral ligament.

We have used so-called cutis grafts in the repair of knee ligaments (Table I). By definition, a cutis graft consists of an excised segment of skin, with or without an underlying layer of fat, from which the epidermal layer has been removed and which has been implanted into the body tissues. We claim no originality for the use of cutis grafts.

We will outline our operative technique for the repair of the tibial collateral ligament of the knee.

The thigh and leg are prepared for operation with soap, water, and alcohol. A median

parapatellar incision is made along the femoral and tibial attachments of the tibial collateral ligament. With a 3/16-inch drill, two holes are made through the medial femoral condyle, about one and one-half inches above the knee and about one inch apart. These drill holes are connected to form a tunnel. A similar procedure is performed on the medial tibial condyle, the holes being made about one and one-half inches below the joint surface.

A skin-graft razor is then used to scrape the epidermis off an area on the lateral aspect of the thigh about two inches wide and eight inches long. A strip of cutis, six to eight inches long and three-quarters to one inch wide, is removed and is split in its upper portion. One split end is drawn through one drill hole in the femur, the other through the other drill hole, and the two protruding ends are sutured to each other with heavy silk. The knee is then held in adduction and flexed to 30 degrees and the other end of the graft is similarly split and placed through the drill holes in the medial condyle of the tibia, considerable tension being maintained. The two sides of the graft are sutured carefully with silk to the surrounding tissue and the wound is closed with catgut and silk.

The wound on the thigh from which the cutis has been removed is now undercut sufficiently so that it may be closed; this is usually done without difficulty. A plaster cast is applied from the upper portion of the thigh to the ankle with the knee flexed to about 30 degrees.

The technique for the repair of the fibular collateral ligament is similar, except that the incision is made laterally and the cutis used is not quite so wide.

Our technique for the repair of the anterior cruciate ligament varies little from the usual procedures except that a cutis graft is used instead of fascia and the graft is attached by the method previously described for the repair of the collateral ligaments. The graft is sutured to the periosteum as well as to itself.

Cannaday was the first American writer to report the use of cutis grafts in hernial repairs in this country. In 1942, he reviewed the literature and presented fourteen cases. In 1943, he reported that cutis grafts had been used in a total of thirty-seven cases, twenty-seven of these cases being hernial repairs.

It was Dr. Cannaday who brought the cutis graft to my attention. Among the cases reported in his 1943 article there was one in which he and I repaired a fibular collateral ligament of the knee by means of a cutis transplant. As far as I know, this was the first instance of the use of a cutis graft in a ligament repair in this country.

Swart reported the use of cutis grafts in six cases of shoulder and wrist injuries with satisfactory results.

## EXPERIMENTAL TESTING OF THE TENSILE STRENGTH OF SKIN AND FASCIA

Studies have been made in Germany by Rehn and others [7, 8] regarding the fate of cutis when it is transposed to a new area and transplanted under the skin. Their conclusion was that in time it assumes the same character as the tissue which it replaces. In other words, if it is used to replace the tendo achillis, it becomes very much like the tendo achillis. If it is used to replace fascial or ligamentous tissue, it becomes very much like that tissue.

We were not able to find any work that had been done regarding the tensile strength of cutis. It is felt that, since the future use of the cutis graft is essentially mechanical, this should be considered.

Charles Murray Gratz, in his work on the tensile strength and elasticity of human fascia lata in 1930, determined that the average tensile strength of fascia lata is 7,860 pounds per square inch. He discovered that recovery from strain at 27 per cent of the breaking load is over 91 per cent. He found that the tensile strength of fascia lata in a female seventy-four years of age was 6,222 pounds per square inch and that the tensile strength of fascia lata in a paralytic female fifteen years of age was 6,375 pounds per square inch.

The author stated: "The above observations presuppose that the sutures are used in such a way that the stress is placed longitudinally in the direction of the fibers, since fascia lata has very little strength in the transverse direction. Operative procedures must be so devised as to bear this in mind. It is hoped that these tests and observations may supplement previous researches and be of value in the clinical use of living suture material. Similar tests of other fascial tissues are contemplated."

The technique for the preparation of the specimens was as follows: The samples of skin and fascia, taken from cadavera in good condition, were approximately one by five inches in size. The loading capacity of the testing machine was limited, and, therefore, it was necessary to prepare specimens that were small enough to break within the limitations of the machine. It was found that skin samples 0.045 inch in thickness should be 0.125 inch wide and that specimens 0.030 inch in thickness should be 0.141 inch wide. Fascia samples did not vary as widely in thickness but their higher strength required that the specimens be 0.188 inch wide when the thickness was only 0.015 inch.

Samples for testing were selected from the total group by visual inspection. Those samples were eliminated which had sustained nicks in removal from the cadaver, which had coatings of fat and fascia adhering to their backs, or which were adjudged to be too thick. The latter were avoided since they necessitated the preparation of very narrow specimens which could not be accurately measured.

The selected samples were placed in an icebox. A single sample was removed, cut into test specimens, measured, and tested on the tensile-testing machine before a second sample was removed from storage. This was done because preliminary work showed that the samples of fascia darkened in color and underwent slight changes in dimensions after prolonged exposures to 80 degrees Fahrenheit.

The test specimens were prepared by grasping one end of a sample with hemostats, placing it on a glass plate, and cutting it into strips of the desired width, a surgeon's knife being used in the cutting and a heavy, straight metal die being used as a straight edge. By placing one end of the die against the jaw of the forceps and drawing the knife away from that end of the sample, the problem of holding the sample was lessened.

The thickness of the skin samples was determined prior to the cutting since in each sample the thickness of the film-like material seemed to be fairly uniform. It appeared best to consider the minimum thickness of a given sample of skin as the thickness of each specimen cut from it. Samples of fascia were cut into test specimens and then measured for thickness. Because of the fibrous nature of fascia, there were considerable variations in thickness across a given sample. Care was taken to prepare each test specimen of fascia tissue in such a manner that the fibers were oriented parallel to the long dimension of the specimen.

The thicknesses were measured with a Federal, Model C-21, dial-type thickness gauge. The instrument was capable of measurements as small as 0.0001 inch. The faces of the instrument which were brought to bear on the sample were round and measured one-quarter of an inch in diameter. When the instrument was operated, there was a pressure of approximately one pound per square inch between the faces which contacted the sample of skin or the specimen of fascia. The skin was compressible at this pressure, and thickness was observed to diminish in proportion to the duration of the contact. The rate of compression was rapid at first and then became very slow. With practice, the point at which the rate of compression became slow could be marked readily; the thickness reading was taken at this point. Such readings were taken at ten to fifteen different places on each sample of skin prior to the cutting of the sample into test specimens. Similarly, the thickness of each specimen of fascia was determined at ten to fifteen different points. The lowest value of thickness found among the ten to fifteen readings was regarded as the value for the entire sample of skin or specimen of fascia. Every specimen cut from a sample of skin was assigned the thickness value found for the sample as a whole.

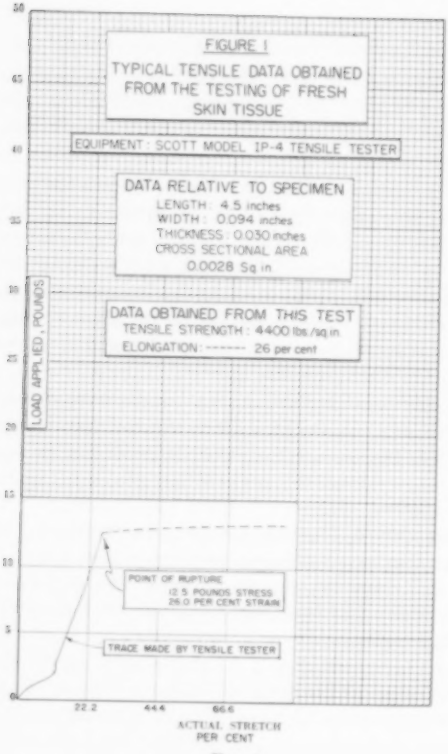


FIG. 1

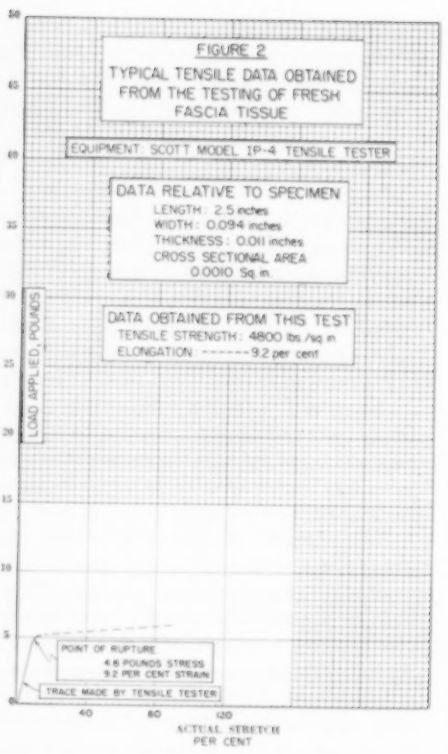


FIG. 2

The width of the specimen was measured to an accuracy of plus or minus 0.008 inch, a machinist's rule being used. The measurement of width introduced the greatest degree of error in the strength determinations.

All of the tests made in this study on the strength and elasticity of human skin and fascia were tensile tests, as opposed to compressional, bending, torsional, or shearing tests.

The tensile tester used was the Scott Model IP-4 Inclined Plane Tensile Tester, a machine commonly employed to determine the tensile properties of yarns, fabrics, and films. The machine is illustrated in Figure 5.

The functions of this machine are to apply an ever-increasing load to the test specimen at a constant rate and to provide a continuous graphic record of the stress and strain behavior of the specimen throughout the test. The photograph shows the machine at rest, its normal state when the specimen is mounted. The specimen is clamped between the jaws of the machine with its lengthwise dimension in the horizontal plane (at zero stress and zero strain). The specimen clamp to the left is fixed; the clamp to the right is attached to a wheel-mounted carriage, to which a recording pen is fastened and upon which masses of various sizes can be placed. In this study, the weight of the carriage and the added mass was fifty pounds. The machine is switched "on", and the plane of the specimen is tilted in the clockwise direction. The rate of "tilting" is controlled by motor-driven gears and pulleys. As the machine tilts, the carriage and its specimen clamp move away from the fixed clamp, elongating the specimen. The pen on the carriage makes a trace on the chart; this trace begins at the origin of the graph (zero load and zero elongation) and continues, forming the characteristic load-elongation curve, until the specimen reaches its breaking point. The load, at any given point on the trace, is obtained directly

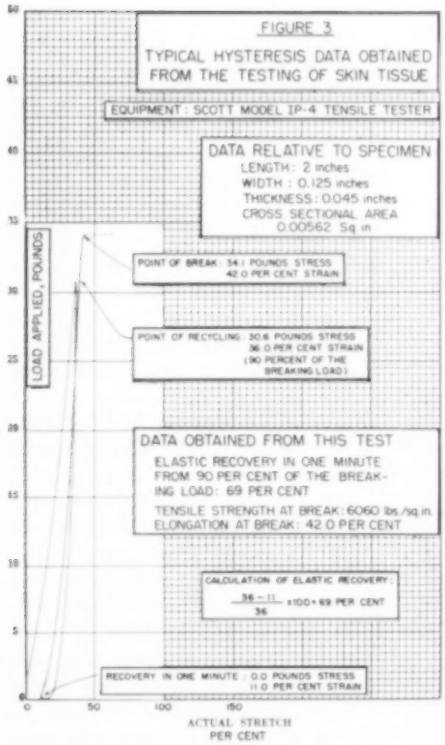
FIGURE 3
TYPICAL HYSTERESIS DATA OBTAINED FROM THE TESTING OF SKIN TISSUE
EQUIPMENT: SCOTT MODEL IP-4 TENSILE TESTER
DATA RELATIVE TO SPECIMEN
LENGTH: 2 inches
WIDTH: 0.125 inches
THICKNESS: 0.045 inches
CROSS SECTIONAL AREA 0.00562 Sq in
POINT OF BREAK: 34 POUNDS STRESS 42.0 PER CENT STRAIN
POINT OF RECYCLING: 30.6 POUNDS STRESS 36.0 PER CENT STRAIN (90 PERCENT OF THE BREAKING LOAD)
DATA OBTAINED FROM THIS TEST
ELASTIC RECOVERY IN ONE MINUTE FROM 90 PER CENT OF THE BREAKING LOAD: 69 PER CENT
TENSILE STRENGTH AT BREAK: 6060 lbs./sq. in.
ELONGATION AT BREAK: 42.0 PER CENT
CALCULATION OF ELASTIC RECOVERY: 36 − 11 / 36 x 100 = 69 PER CENT
RECOVERY IN ONE MINUTE: 0.0 POUNDS STRESS 11.0 PER CENT STRAIN
LOAD APPLIED, POUNDS
ACTUAL STRETCH PER CENT

FIG. 3

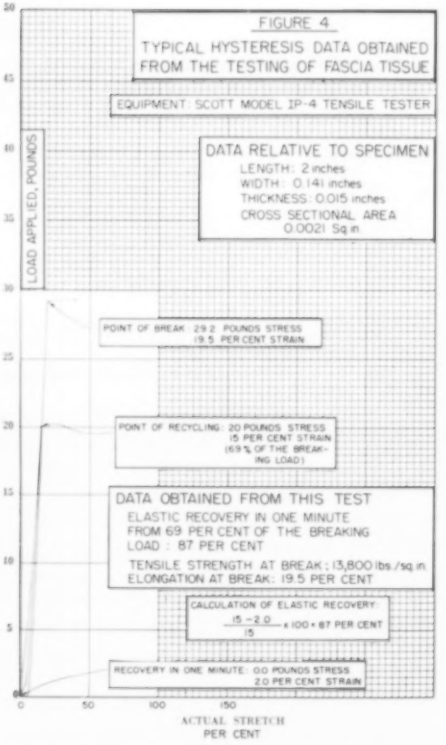
FIGURE 4
TYPICAL HYSTERESIS DATA OBTAINED FROM THE TESTING OF FASCIA TISSUE
EQUIPMENT: SCOTT MODEL IP-4 TENSILE TESTER
DATA RELATIVE TO SPECIMEN
LENGTH: 2 inches
WIDTH: 0.141 inches
THICKNESS: 0.015 inches
CROSS SECTIONAL AREA 0.0021 Sq in
POINT OF BREAK: 29.2 POUNDS STRESS 19.5 PER CENT STRAIN
POINT OF RECYCLING: 20 POUNDS STRESS 15 PER CENT STRAIN (69% OF THE BREAKING LOAD)
DATA OBTAINED FROM THIS TEST
ELASTIC RECOVERY IN ONE MINUTE FROM 69 PER CENT OF THE BREAKING LOAD: 87 PER CENT
TENSILE STRENGTH AT BREAK: 13,800 lbs./sq. in.
ELONGATION AT BREAK: 19.5 PER CENT
CALCULATION OF ELASTIC RECOVERY: 15 − 2.0 / 15 x 100 = 87 PER CENT
RECOVERY IN ONE MINUTE: 0.0 POUNDS STRESS 2.0 PER CENT STRAIN
LOAD APPLIED, POUNDS
ACTUAL STRETCH PER CENT

FIG. 4

by reference to the vertical scale (axis of ordinates). The elongation, at any given point on the trace, is determined by dividing the length of the extended specimen, as indicated on the horizontal scale (axis of abscissas), by the original length of the specimen and multiplying the quotient by 100; the result is expressed as a per cent. The original length of the specimen is the length of the specimen after it has been placed between the clamps of the tensile tester in preparation for testing.

The specimens were placed in the jaws of the testing machine with their ends lapped back and were clamped to the taut portion between the jaws by means of hemostats. The use of the hemostats was necessitated by the lubricating effects of the fats and oils in the specimens. The hemostats probably exerted very little shearing stress perpendicular to the lengthwise axis of the test specimen.

The data obtained from the tensile tests are presented in the figures and tables which are appended to this paper (Figs. 1 through 4; Tables II through IV).

The cadaver material, which was obtained from the Medical College of Virginia through the courtesy of Dr. H. L. Osterud, Professor of Anatomy, was kept moist at all times and was stored in the icebox. When an individual piece was taken out for study, the remainder of the tissue was promptly returned to the icebox.

We found that fascia had an average tensile strength of 9900 pounds per square inch. Skin, on the other hand, had an average tensile strength of 7500 pounds per square inch. In other words, skin was 24 per cent weaker than fascia. The data from which these values were derived are presented in Table III.

We also determined the ultimate elongation of each specimen, that is, the amount the specimen was elongated when it was at the breaking point. The ultimate elongation

TABLE II

TENSILE DATA OBTAINED FROM THE STUDY OF FRESH SKIN AND FASCIA TISSUE

| Type of Tissue | Test Number | Tensile Strength (*Pounds per Square Inch*) | Ultimate Elongation (*Per cent*) |
|---|---|---|---|
| Skin | 1 | 4400 | 26 |
| | 2 | 4320 | 26 |
| | Weighted average | 4360 | 26 |
| Fascia | 1 | 4800 | 9.2 |
| | 2 | 5300 | * |
| | Weighted average | 5100 | 9.2 |

* Value in error due to slip in jaws of tensile tester.

of fascia averaged 16 per cent, while the ultimate elongation of skin averaged 40 per cent. In brief, the ultimate elongation of skin was 150 per cent greater than that of fascia. These values were derived from the data presented in Table III.

We also made hysteresis curves to show energy loss. In these tests, a certain percentage of the breaking load was placed on the skin or fascia. The load was then removed in order to determine how closely the tissue came back to its original length.

It was found that when 68 per cent of the breaking load was used, the elastic recovery of skin, that is, the amount of recovery obtained within one minute, was 78 per cent. With 90 per cent of the breaking load, skin had an elastic recovery of 69 per cent. Fascia, on the other hand, at 69 per cent of the breaking load, had an elastic recovery of 87 per cent. In other words, fascia does recover more quickly from stretching than skin. These values were derived from the data which are presented in Table IV (see also Figs. 3 and 4).

Hysteresis measurements were made in the following manner: The specimens were mounted for testing exactly as in the simpler tests. The machine was started and was permitted to increase the load until it equaled a predetermined percentage of the breaking load for similar specimens. At that point, by means of the gearshift lever shown in the photograph (Fig. 5), the tilting motion of the machine was reversed. As the plane of the specimen was tilted back toward the horizontal, the recovery power of the specimen caused the carriage to move back toward the fixed clamp. The time at which the specimen returned to the horizontal (zero load) was noted, and one minute was allowed for addi-

TABLE III

TENSILE DATA OBTAINED FROM THE STUDY OF SKIN AND FASCIA FROM CADAVERA

| Type of Tissue | Test Number | Number of Determinations per Test | Tensile Strength (*Pounds per Square Inch*) * | Ultimate Elongation (*Per cent*) |
|---|---|---|---|---|
| Skin | 1 | 3 | 9180 | 45.2 |
| | 2 | 3 | 5740 | 39.2 |
| | 3 | 3 | 5370 | 37.8 |
| | 4 | 5 | 8760 | 38.0 |
| | | Weighted average | 7500 | 40.0 |
| Fascia | 1 | 5 | 11500 | 17.1 |
| | 2 | 5 | 5920 | 12.4 |
| | 3 | 5 | 12800 | 19.1 |
| | 4 | 7 | 9400 | 14.1 |
| | | Weighted average | 9900 | 16.0 |

* The tissue obtained from cadavera was fixed. Its greater strength, as compared to fresh tissue (Table II), is presumed to be the result of this fixation.

TABLE IV

DATA OBTAINED IN THE STUDY OF THE ELASTIC RECOVERY OF SKIN AND FASCIA TISSUE

| Type of Tissue | Test Number | Portion of Breaking Load Used (*Per cent*) | Elastic Recovery (*Per cent*) |
|---|---|---|---|
| Skin | 1 | 68 | 78 |
| | 2 | 90 | 69 |
| Fascia | 1 | 69 | 87 |
| | 2 | 98 (approximately) | 74 |

tional recovery of the specimen. The machine was then started again and was permitted to break the specimen. Elastic recovery was calculated as follows: The amount of elongation after recovery at zero load for one minute was subtracted from the amount of elongation at the point of recycling; the difference between these two amounts was divided by the amount of elongation at the point of recycling and the quotient was multiplied by 100; the result was expressed as a percentage. The load at the point of recycling was divided by the breaking load of the specimen in order to determine what percentage of the breaking load had been used. Perfect elasticity would have been exhibited had any of the specimens recovered to zero elongation after recycling. Zero hysteresis (energy loss) would have been exhibited had the recovery curve superimposed itself on the loading curve.

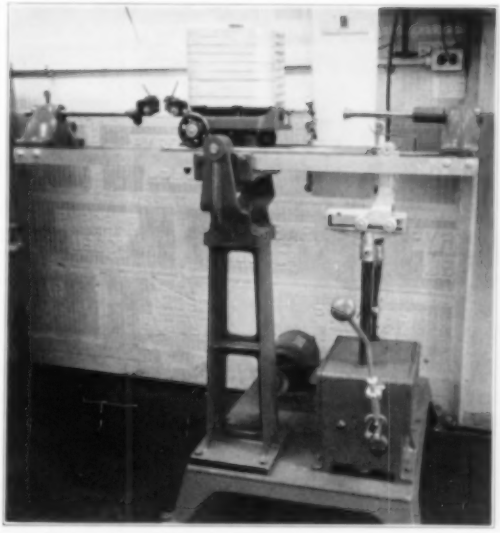

FIG. 5

In the study of fresh material, it was found that skin had a tensile strength of 4400 pounds per square inch. Fascia, when the same testing technique was used, had a strength of 5100 pounds per square inch. This would indicate that skin is 14 per cent weaker than fascia when fresh tissue is used. The small quantities of fresh tissue available limited this test to only two determinations for both skin and fascia.

Skin had an average ultimate elongation of 26 per cent before breaking. On the other hand, fascia had an average ultimate elongation of 9.2 per cent, which would indicate that fresh fascia will not stretch or elongate as much as fresh skin. Typical data obtained from tensile tests made on fresh tissue are presented in Table II (see also Figs. 1 and 2).

On the basis of these data it would seem at first glance that it makes no great difference which tissue is used. However, we must consider that cutis, as used in the cutis graft, is two to five times thicker than fascia, and for that reason a cutis graft is definitely mechanically stronger than a fascial graft.

## CASE REPORTS

CASE 1. M. E. D., a white coal miner, forty-three years of age, was injured on January 15, 1942, when his right thigh was hit by coal and rock. He stopped work immediately. He used two crutches for three weeks and then used one crutch up until May 12, 1942, when he was first seen by us.

He complained that his "leg gave out on him" and that his knee ached.

Examination showed a fairly well developed and nourished white man who walked with a limp of the right lower extremity. Synovial thickening was present in the right knee. There was marked relaxation of the fibular collateral ligament. There was some grating of both knees on motion.

A brace was recommended and was applied on June 13, 1942. When he was examined on August 28, 1942, he still had marked relaxation of the fibular collateral ligament in the right extremity, and operation was advised.

He was operated upon at the Charleston General Hospital on October 1, 1942, at which time a cutis graft was used to construct a new fibular collateral ligament.

Examination on December 1, 1942, showed that the new ligament was holding well. He still had some quadriceps weakness. He was last seen on May 6, 1943, at which time he had no relaxation of the fibular collateral ligament. Flexion was present to 70 degrees. Extension was complete. He returned to work in June 1943, and for a time operated a mine motor.

Every effort has been made to trace this man since that period. He worked steadily in the mines for a number of months and then moved, and we have been unable to find him since.

Case 2. R. C., a white male, twenty-seven years of age, was examined on behalf of the West Virginia State Compensation Department on May 20, 1943. He had been injured in the mines on September 19, 1940, sustaining a fracture of the lower portion of the right femur; this fracture extended into the knee joint.

Examination in May 1943, revealed that he walked with a slight limp of the right lower extremity. He had some swelling, stiffness, and tenderness of the right knee. There was marked relaxation of the tibial collateral ligament. The other ligaments were normal. The right patella was only slightly less movable than the left. There was some grating of the right knee on motion.

He had a one-inch shortening of the right lower extremity, and the circumference of the right thigh was one inch less than that of the left. The right knee flexed to 130 degrees, the left to 42 degrees.

Operation was performed on July 2, 1943, at the Charleston General Hospital.

He was examined at intervals and was last seen January 23, 1945. Examination at this time showed that he had very slight limp of the right lower extremity. There was some grating of the right knee on motion, but there was no significant relaxation of the tibial collateral ligament. Flexion of the knee was present to 60 degrees, and extension was complete. This man does have considerable traumatic arthritis. His injury was classified as a 40 per cent partial permanent disability due chiefly to the presence of the traumatic arthritis; chief concern was with the old fracture and the traumatic arthritis.

Results in this case were considered excellent from the standpoint of the ligament repair.

Case 3. O. W., a white male, twenty-four years of age, was first seen on May 28, 1943, complaining of pain and inability to flex the right knee. He had been injured on January 26, 1940, when he had been caught between a coal car and a post. He had worn a cast for about four months; a knee brace had then been applied which he had worn for eight months. On September 16, 1943, the lateral meniscus of the right knee had been removed at the Mountain State Hospital in Charleston. He had had no other treatment. He had been placed on light duty at work three months after this operation.

Examination showed a white male who limped slightly on the right lower extremity. There was an operative scar on the medial aspect of the right knee. There was very marked relaxation of the anterior cruciate ligament, but the other ligaments were intact. Extension of the right knee was normal. Flexion of the right knee was present to 128 degrees and flexion of the left to 50 degrees.

Operation was performed on July 14, 1943, at which time the anterior cruciate ligament was repaired by means of a cutis graft.

He was able to discard his brace on September 17, 1943. At that time, there was practically no relaxation of the anterior cruciate ligament.

In February 1944, it was found necessary to remove some of the silk material used to suture the cutis graft to the medial condyle. The cutis graft was found to be in good condition and well fixed to the tibia.

The patient returned to work in the coal mines in February 1944, eight months after the operation.

This man was last examined on August 13, 1955. He had been working regularly inside the mine, at times in tunnels only three feet three inches high. He had had little or no trouble with his right knee, but rheumatism had developed in the left knee.

Examination showed good muscle power, and he was able to squat well. Motion was normal, there was no crepitation, and there was no relaxation of the anterior cruciate ligament. Roentgenographic findings were negative.

CASE 4. B. L. P. was first seen in 1937, at the age of thirteen years, with extensive osteomyelitis of the left femur. Her general condition was very poor at that time and soft-tissue drainage only was instituted. She weighed only about forty-five pounds.

She improved rapidly, however, and was seen at intervals in the West Virginia State Crippled Children's Clinic. In the period of one year, from the middle of 1938 to the middle of 1939, she gained seventy-five pounds, which brought her weight up to 120 pounds. It was first noted in June 1939, that she had marked relaxation of both collateral and cruciate ligaments of the left knee. A knee brace was obtained and quadriceps exercises were emphasized. She improved slightly, but it was recognized in June 1943, that either an arthrodesis or an operative repair of the ligaments would have to be done.

On June 10, 1943, the fibular collateral ligament was repaired by means of a cutis graft; in September 1943, the tibial collateral ligament was repaired by a cutis graft; and on August 8, 1944, repair of the anterior cruciate ligament was done. At this time the fibular collateral ligament had to be resutured due to the fact that it had not been sutured under sufficient tension in the first operation.

She was last seen in October 1945, at which time there was relatively slight relaxation of any of the ligaments and there was no functional disability. She could walk long distances without difficulty. She had, of course, discarded her brace.

CASE 5. D. B., a white female, eighteen years of age, was first seen on December 3, 1952. She had fallen off a truck and injured her right knee.

Examination showed marked swelling of the right knee and marked lateral instability. There was also marked relaxation of the fibular collateral ligament. Roentgenograms showed a compression fracture involving the medial plateau of the right tibia with the fragments in a relatively good position.

A cast was applied which she wore for eight weeks. After its removal, a brace was applied and she was given weight exercises.

On June 23, 1953, six months later, she still had very marked relaxation of the fibular collateral ligament.

On July 17, 1953, a cutis-graft repair of the fibular collateral ligament was performed. Staples were used to fasten the cutis to the bone after the cortex had been roughened at the point of insertion of the cutis graft, above and below the knee joint. The cast was removed on August 18, 1953, and a brace re-applied.

She was treated by means of weight exercises until October 1953.

The staples which had been placed above and below the knee joint in order to fasten the cutis graft to the tibia were prominent and gave some irritation; on July 13, 1955, they were removed. A specimen of skin was removed at the same time, but due to error it was not examined for three days and was thus rendered useless for histological examination.

She was last seen on August 23, 1955. She had fair correction, but there was still some relaxation of the fibular collateral ligament. She stated that she had no trouble whatsoever with the function of the knee. She was able to do all her housework satisfactorily, and she had no pain in the knee.

In approximately ten other cases cutis grafts have been used in the repair of knee ligaments. Tabulation and follow-up in these cases have not yet been completed.

## CONCLUSIONS

Skin has less tensile strength, elongates more readily, and loses more energy than fascia. However, it has certain advantages over fascia due to its greater thickness and to its lesser tendency to fray.

It has been used successfully in five cases for the repair of torn knee ligaments.

NOTE: This study was made possible through the cooperation of the Carbide and Carbon Chemicals Company of South Charleston, West Virginia, which tests materials of all kinds. Acknowledgement is made to Dr. E. W. Rugeley and Mr. T. A. Feild for their generous assistance and to Mr. C. W. Davisson for his help with the technical aspects of the study.

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# The Perpendicular in Relation to Walking Casts

BY DR. R. RUDING, BREDA, THE NETHERLANDS

The placement of a walking iron or heel on a walking plaster cast is of some importance. In order to permit free rocking motion of the foot during gait, these appliances are made to have only a small contact surface with the ground. They must therefore be placed exactly beneath the center of gravity in order to avoid abnormal stresses on the foot and the leg within the cast during standing and walking.

In order to determine the exact location of the point where the perpendicular from the center of gravity intersects the supporting plane of the foot, a study of ninety healthy army recruits was carried out. The data for the study were obtained during routine physical

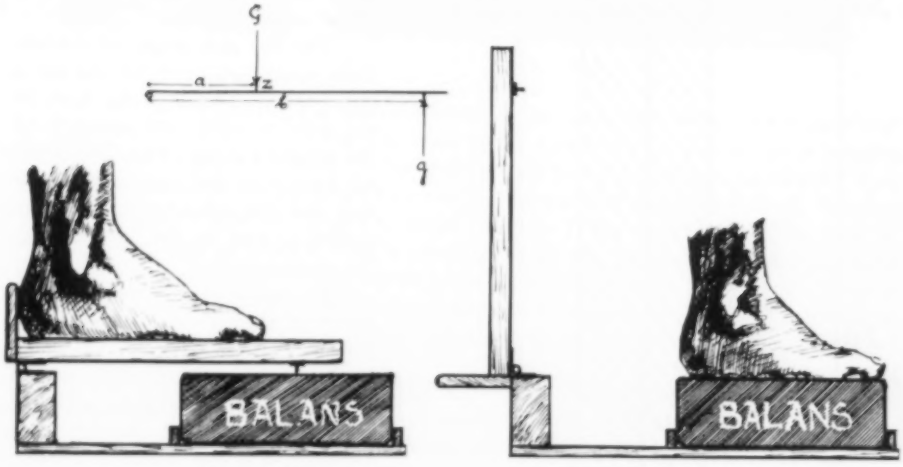


FIG. 1-A

FIG. 1-B

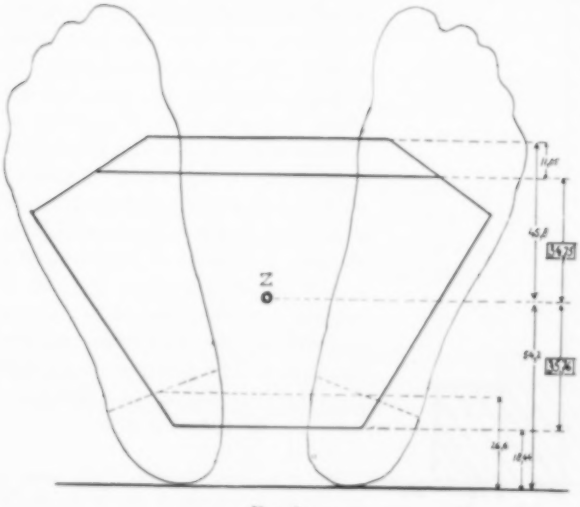

FIG. 2

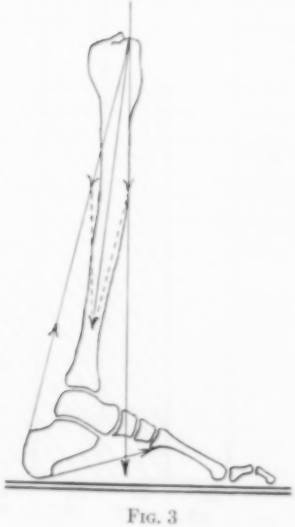

FIG. 3

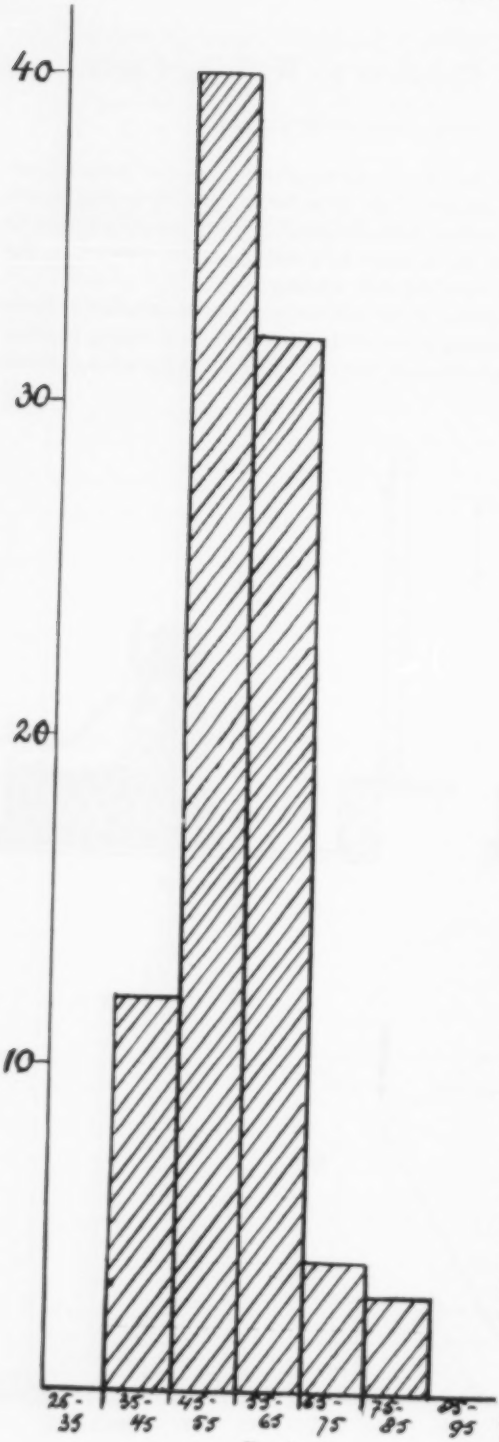


FIG. 4

examination and included (1) the subjects' height and weight, (2) the distances between the back of the heel and the inner and outer malleoli, respectively, (3) the mid-point between the heel-to-malleolar distances which was considered the site of the ankle-joint, (4) the distances between the back of the heel and the first and fifth metatarsal heads, respectively, (5) the mid-point between the heel-to-metatarsal-head distances which was called the "anterior foot", and (6) the site and extent of the lordosis.

The site and extent of the lordosis was determined by placing a lath vertically against the back in the mid-line with light pressure, as the subject was standing. The greatest horizontal distance between the lath and the subject's skin was recorded as well as the level of this line on the spine.

By means of an apparatus similar to that used by Reynolds and Lovett (Fig. 1-A), the point of intersection of the perpendicular dropped from the center of gravity with the supporting plane of the foot was determined in the following fashion: the body weight with the subject standing on the platform (g) was determined, and then the true body weight (G) was recorded with the subject standing on the balance (Figs. 1-A and 1-B). The point of intersection of the perpendicular dropped from the center of gravity with the supporting plane of the foot was called $Z$; the distance of $Z$ from the axis of rotation of the foot-plate, $a$, and the distance from the axis of rotation of the foot-plate to the support of the foot-plate on the balance, $b$. The location of $Z$ could then be calculated as follows:

$$G \times a = g \times b$$

Fig. 4: *Abscissa:* Position of the point of gravity in percentage of the length of the foot, reckoned from the heel.
*Ordinate:* Number of persons measured.

FIG. 5

FIG. 6

This location of the point *Z* was calculated on the ninety military recruits examined.

In addition, lateral roentgenograms of six feet in standing position were made in order to compare the distance between the back of the heel and the first metatarsal head with the distance between the calcaneal tuberosity and the first metatarsal head. Average measurements were determined and recorded (Fig. 2). If the distance from the back of the heel to the first metatarsal head is assumed to be one hundred, then the following average values were found, measuring from the back of the heel: heel to point *Z*, 54.2; heel to center of the ankle joint, 26.6; heel to calcaneal tuberosity, 18.44; heel to the anterior portion of the foot, 88.95 (100 − 11.05); calcaneal tuberosity to the anterior portion of the foot, 70.51 (35.76 + 34.75).

The ankle joint, therefore, lies midway between point *Z* and the back of the heel, and point *Z* is almost midway between the "anterior foot" and the calcaneal tuberosity (34.75 + 35.76 = 70.51). Therefore, since the perpendicular from the center of gravity of the body passes through the knee, the tibia bisects the angle formed by this perpendicular and the direction of the pull of the calf muscle and the Achilles tendon (Fig. 3). Should the perpendicular fall more to the posterior, the stability of the ankle in standing would be decreased.

Attempts to correlate the location of the perpendicular from the center of gravity with the body weight, body height, site of the ankle joint, differences in location of the first and fifth metatarsal heads, and the site and extent of the lordosis were unsuccessful. No correlations were found (Fig. 4).

The point at which a walking heel should be placed is, therefore, (1) midway between the calcaneal tuberosity and the "anterior foot" (the mid-point on a line connecting the first and fifth metatarsal heads), or (2) just anterior to the mid-point of the line joining the ball of the foot and the back of the heel (Fig. 5).

When a walking cast is used the shoe of the patient's normal side should be built up with a cork sole to level the pelvis.

Figure 6 shows the heel of the walking cast in correct position. By such placement of the heel it has been our experience that convalescence after surgery or after fracture has been shortened and the time needed for plaster immobilization reduced.

## REFERENCE

1. REYNOLDS, E. S., and LOVETT, R. W.: Method of Determining the Position of the Center of Gravity in its Relation to Certain Bony Landmarks in Erect Position. Am. J. Physiol., **24**: 286–293 1909.

# A Splint for Medial Tibial Torsion

BY WALTER P. BARNES, JR., M.D., MACON, GEORGIA

It is recognized that medial torsion of the tibia often occurs in association with other deformities, such as congenital club-foot, talipes valgus, flat-foot, and metatarsus varus. Although in the literature there is a paucity of information on the treatment of medial torsion of the tibia associated with flat-foot, in a general orthopaedic practice it is not uncommon to see both of these deformities in the same patient (Fig. 1). It is important, while treating medial torsion of the tibia, to direct some effort to the preservation of foot balance, so that as the torsion is being corrected, no untoward deformity in the foot will develop or be aggravated.

The purpose of this presentation is to introduce a splint that will correct medial torsion of the tibia and at the same time hold the foot in a controlled position.

In treating medial torsion of the tibia we are accustomed to using what is called a modified Denis Browne splint. The gentle rotatory force maintained by this splint over a period of time corrects the medial torsion; it may also cause pronation of the feet, however, and in some cases it even produces flat-foot. If the child already has medial torsion and flat-foot before treatment is started, we should have as our aim the treatment of both deformities at the same time. The usual treatment with special shoes, wedges, and arch supports is not to be discarded. It is important for the mother to observe the child closely so that she may correct faulty sitting habits which aggravate medial torsion.

Since treatment with the usual modified Denis Browne splint entails the possibility

Fig. 1: A posterior view of a child with medial tibial torsion. Note the valgus position of heels and the lack of arches in the medial portion of the feet.

Fig. 2. A posterior oblique view showing how the brace holds the feet in a position of inversion. The longitudinal axis of the right foot is at about a right angle to that of the left. Despite this inversion is still maintained.

FIG. 1

FIG. 2

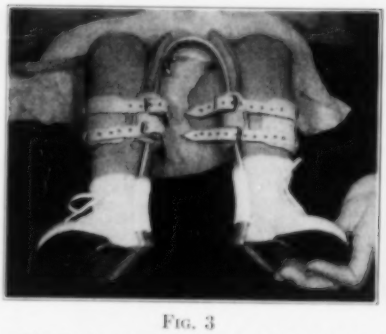

FIG. 3

FIG. 4

Fig. 3: An anterior view of a child with the knees flexed. The knees are held close to the pads by calf bands.

Fig. 4: The same child shown in Fig. 3. The calf bands have been loosened. Note the loss of inversion of the feet.

of producing flat-foot or aggravating pre-existing pronation of the foot, we must seek another simple means of treating these co-existing deformities. The position of correction is lateral rotation of the lower extremities, with inversion of the feet. The usual straight-bar splint will maintain the former. If the shoes are set at right angles to the bar, the bar may be bent so as also to hold the feet in a position of moderate inversion. However, if more than moderate lateral rotation and inversion are required, another factor comes into play. It is then noted that the degree of inversion diminishes as the position of the shoe is adjusted to obtain more lateral rotation of the extremity, so that when the shoe is in a position for lateral rotation of 90 degrees, there is no inversion but only equinus.

## THE SPLINT

A splint has been fashioned and used since 1953 which will maintain inversion of the feet while the lower extremities are laterally rotated. It is called an A-frame splint, because of its similarity to the letter *A*. It consists of metal foot-plates riveted to the soles of high-top shoes, attached to which is a long, flat, aluminum-alloy bar, bent at the foot and again at the knee. There is a calf band and a knee pad for each side. The shoe can be inverted easily by manually bending the metal bar near the sole of the shoe, and lateral rotation is attained by grasping the proximal portion of the splint and twisting the bar laterally by manual force (Fig. 2). As an extra precaution against aggravating flat-foot, a felt pad may be taped to the upright bar against the medial malleolus, so that when the calf band is tightened, the foot will not be brought into a valgus position.

## USE OF THE SPLINT

It is generally known that in most cases of medial torsion spontaneous correction occurs with growth. For this reason the splint is not used prior to six months of age. During that time treatment consists in derotation exercises carried out by the mother. If no improvement occurs by six months, the splint is instituted. It has not been used in a child over five years of age but is effective in children up to that age. It is not intended as the sole means of treating foot deformities *per se*, but allows varus or valgus positions of the foot to be controlled.

The splint is used at night when the child is asleep. When the child flexes the knees and hips, the effect of lateral rotation is restricted to the knees and is not dissipated to the hips; the greatest effect on the tibiae is actually produced when the child has the knees and hips flexed (Fig. 3). However, when the child's hips and knees are extended, the feet are still not allowed to turn in. The calf bands contribute to the prevention of a valgus position of the feet and keep the knees from separating, thus exerting upon the lateral aspect of the calves a force which tends to correct the tibial bowing (Figs. 3 and 4). The knee pads may be adjusted to different heights, depending on the rate of growth of the child and the degree of inversion desired. In cases of unilateral deformity the unaffected extremity can be held in a neutral position.

## CONCLUSION

It is believed that this splint affords a much more effective method for correction of medial tibial torsion, either as a single entity or in association with foot deformities, than has been presented heretofore. Many severe deformities which ordinarily would require expensive walking braces may be corrected with the more economical A-frame splint. The duration of treatment is shortened, and no untoward effects are produced.

# Proceedings

## AMERICAN ORTHOPAEDIC ASSOCIATION

Wednesday, June 20, 1956

**Cervical-Spine Fractures and Dislocations. Dependent Head Traction.** Dr. Hira E. Branch[1] reported his experience with dependent head traction in the reduction of compression fractures and anterior dislocations of cervical vertebral bodies. In this procedure, which was first reported by Dr. J. T. Nicholson in 1940 [a], the patient lies supine upon built-up mattresses with his head at the foot of the bed. The portion of the neck distal to the fracture rests on the edge of the top mattress, while the proximal portion is dependent. When the patient is in this position, the cervical spine is arched and traction is exerted by the weight of the patient's head. This position should be maintained for three weeks, after which external fixation, consisting of a pelvic-support back brace with a cervical-traction brace attachment, is applied.

The author stated that if reduction is not obtained by this means, manipulation may be done. In this procedure the patient is placed in the same position and a general anaesthetic is given. Traction and rotation of the head and neck laterally is then done in order to disengage and realign the locked lateral articular processes.

The author reported the results obtained in twenty-three patients, three of whom had injuries of long standing (eight to seventy-five days) and twenty of whom had recent injuries. In the total series, only three results had been classified as anatomically unsatisfactory, while in 75 per cent of the patients reduction had been achieved. There had been one death (as a result of transection of the cord at the level of the fourth cervical vertebra, a complication which had been present when the patient was admitted to the hospital), and one patient had undergone open reduction and spine fusion.

a. Nicholson, J. L. Spontaneous Reduction of Cervical Spine Dislocations. J. Am. Med. Assn., **115**: 2063–2069, 1940.

**Further Evaluation of the Use of Intramedullary Nailing in the Treatment of Gunshot Fractures of the Extremities.** Col. Ernest A. Brav[2] presented the results of a further study of the treatment of fractures by intramedullary nailing. In 1952, he and Dr. V. A. Jeffress [a] had reported a two-year follow-up study of eight femoral fractures caused by gunshot. In these cases infection had been a complication and the fractures had been treated by intramedullary nailing. Since 1952, two cases had been added to the series, making a total of ten cases. In all of these ten cases satisfactory union of the fractures had been obtained. One patient had had fibrous union and three had had some intermittent residual wound drainage.

In the present article the author was principally concerned with United States Army Korean War casualties. Eighty-five reports of gunshot fractures treated by intramedullary nailing had been found. The patients had not been available for individual examination, but data had been accumulated from their records and from questionnaires sent to them. Sufficient data had been available (from sixty-seven cases) to enable the author to draw the following conclusions: the over-all percentage of satisfactory results had been 88.6 per cent. When the nailing had been done prior to wound healing, the results had been satisfactory in 89.3 per cent of the patients; when the wound had been left open after nailing, the results had been satisfactory in 91.7 per cent of the patients; and when the nailing had been done after wound healing was complete, the results had been satisfactory in 88.1 per cent of the patients.

In two patients in whom immediate closure had been done in the presence of infection, complete failure had occurred, resulting in amputation in one of the patients and in infection and non-union in the other. Amputation had also been necessary in one patient in whom the wound had been left open.

The author listed the indications and contra-indications for nailing of gunshot fractures. It is considered that the method is applicable in selected cases but should never be used at the time of primary débridement.

a. Brav, E. A., and Jeffress, V. H.: Modified Intramedullary Nailing in Recent Gunshot Fractures of the Femoral Shaft. J. Bone and Joint Surg., **35-A**: 141–152, Jan. 1953.

**Clinical Survey of 163 Cases of Internal Fixation with Metal in Fractures in Children.** Dr. Jean Verbrugge[3] presented a factual report of the results of metal internal fixation of fractures in 163

[1] 821 Mott Foundation Building, Flint, Michigan.
[2] United States Army Hospital, Neubrucke, A.P.O. 34, New York, N. Y.
[3] 75 Avenue van Ryswyck, Antwerp, Belgium.

children under fifteen years of age, followed from one to twenty years. His purpose was to record his experience for the benefit of surgeons who may be forced by lack of the materials necessary for conservative treatment to resort to the use of metal internal fixation of fractures in children. The majority of the children had been five to nine years of age, and the majority of the fractures had involved the elbow, femur, or forearm. The author emphasized that these cases represented only 8 to 10 per cent of the total number of fractures in children which he had treated. Although the author preferred to use stainless steel for internal fixation, he had also used soft iron (for wiring and nailing but not for plating or screws), ordinary steel, aluminum (one patient had been treated by means of an aluminum plate and steel screws without any untoward result), and an alloy of magnesium and aluminium (the latter caused a local reaction with formation of gas in the tissues). Open fracture was not regarded as a contra-indication to the use of internal fixation. There had been no deaths in this series, and there had been only two instances of temporary infection. The results had been rated as *good* in 159 of the 163 patients, *fair* in three, and *poor* in one (the latter was thought to be due to faulty technique).

**Fundamental Studies in the Design of Metal Screws for Internal Fixation of Bone.** Dr. Charles O. Bechtol [4] and Dr. Henry Lepper, Jr.[5], presented the results of some of their experiments on the design of metal screws for use in internal fixation. By a standard technique bending fractures had been produced in pairs (right and left) of dog bones. Surprisingly similar strengths had been found in each pair even though studies of thin ground sections taken from the bones had revealed that bone is a non-isotropic material.

It had been estimated that approximately 15 per cent of the total volume of each bone studied was occupied by cells, canaliculi, and Haversian systems. Within the pattern of living Haversian systems were remnants of old avascular systems. It had been found that these remnants were more susceptible to fracture than were the living Haversian systems and that they increased in number as the bone aged. A hole of any size in these bones reduced their breaking strength, the weakening effect being greatest when the holes were placed on the side of the bone under tension when bending stress was applied. Any splitting of the bone about a hole or screw also greatly reduced the breaking strength of the bone. The size of the hole had little influence on the breaking strength if its diameter was less than 20 per cent of the diameter of the bone; but if it was more than 20 per cent, the weakening effect increased in direct proportion to the size of the hole. The presence of a screw in a bone produced an effect comparable to that produced by a hole equal in size to the outside diameter of the screw. However, as new bone was laid down about the screw as the result of healing, this weakening effect was decreased. The optimum size hole for a screw was found to be one with a radius approximately half way between the radius of the threads of the screw and the radius of the root of the screw. The screws held best if they were inserted with a torque which was approximately equal to 75 per cent of the torque necessary to strip the threads in the bone. The holding power of the screws improved with time as a result of bone healing even when the threads in the bone had been stripped. Screws penetrating both cortices were best able to withstand either a direct pull-out force or a force applied parallel to the bone surface. Studies of the design of the screw threads and of the flutes in the self-tapping points suggested that although the type of thread made little difference, the shape and size of the flutes were of importance.

Thursday, June 21, 1956

**Spine Fusion in Children.** Dr. Halford Hallock [6], Dr. Kenneth C. Francis [7], and Capt. James B. Jones [8] had made a study of sixteen patients, two to eight years of age, upon whom spine fusion had been performed for tuberculosis of the thoracic, thoracolumbar, or lumbosacral vertebral bodies. The purpose of this study had been to determine the effect of posterior fixation upon the subsequent growth of the fused vertebrae. These patients had been followed for an average of twenty-one years—that is, until they had reached an average age of twenty-four years—with the result that there could be no question that all (except perhaps one) had achieved full growth.

By means of a method of measurement devised by Albert Ferguson, the authors had determined that successful spine fusion in a young child retards the growth of the fused vertebrae to a small but measurable degree. This retardation is more apparent in the posterior elements than in the anterior elements, and occurs in both the old diseased areas and the undiseased vertebrae which have been included in the fusion area on either side of the obviously diseased vertebrae.

The final conclusion of the authors was that the diminution in trunk growth found in these patients was relatively insignificant and was perhaps mainly the result of the destruction of the vertebral bodies by the disease.

[4] 789 Howard Avenue, New Haven, Connecticut.
[5] New Haven, Connecticut.
[6] 180 Fort Washington Avenue, New York, N. Y.
[7] Presbyterian Hospital, New York, N. Y.
[8] United States Air Force Hospital, Barksdale, Air Force Base, Louisiana.

**Vertebral Growth and Spine Fusion.** Dr. Joseph C. Risser[9] discussed the growth effects and complications which may develop when spine fusion is performed in early or late childhood. He believed that the fused section elongates with growth of the vertebral body. The vertebral growth occurs at the expense of the intervertebral spaces, and the fused section elongates as a result of the distracting force exerted by this growth. It was his opinion that the fused section possesses biological plasticity and is subject to the bending stresses which are exerted above or below it. This is particularly well illustrated in patients who have a lordosis or an additional curve above or below the area of fusion. The author's conclusions were based upon the study of one of the largest scoliosis series in this country.

**Surgical Approaches to the Vertebral Bodies in the Cervical and Lumbar Area.** Dr. W. O. Southwick[10] and Dr. Robert A. Robinson[11] discussed surgical approaches to the vertebral bodies of the cervical and lumbar spine. The approaches they recommended may be used not only in diagnosis but also in the treatment of vertebral lesions.

For exposure of the bodies of the upper three cervical vertebrae, the authors pointed out the feasibility of the pharyngeal approach through the open mouth. With the patient under endotracheal anaesthesia, a longitudinal incision is made in the relatively avascular mid-line portion of the pharynx, following which the vertebral bodies may be visualized. Closure is accomplished by catgut sutures. These are placed loosely over a rubber drain, which is secured to a piece of silk suture; the silk suture, in turn, is passed through the nose and taped to the cheek in order to prevent its being swallowed.

The anterior approach is advocated for the exposure of lesions at the level of the third cervical vertebra or below. With the patient under endotracheal anaesthesia, a transverse incision is made at the level of the cricoid cartilage, the platysma being cut in the same line. A longitudinal incision through the fascia anterior to the sternocleidomastoid is then made, and the pretracheal fascia is incised longitudinally slightly lateral to the mid-line. The carotid sheath is retracted laterally and held in that position while the trachea, oesophagus, and thyroid gland are retracted medially. A longitudinal incision through the anterior longitudinal ligament completes the exposure. Care must be taken not to damage the oesophagus, vertebral artery, recurrent laryngeal nerve, sympathetic fibers, or carotid vessels during this exposure.

In the lumbar area the usual sympathectomy approach affords access to the bodies of the fourth and fifth vertebrae. By extension of the incision upward and resection of a portion of the twelfth rib, the retroperitoneal space may be entered; if the peritoneum is then reflected forward, the bodies of all the lumbar vertebrae may be adequately visualized.

The sympathetectomy approach is more extensive than is the posterolateral approach, in which an incision is made along the lateral border of the sacrospinalis. In the posterolateral approach, following completion of the incision, the sacrospinalis is reflected medially in order to expose the transverse process of the involved vertebra. The lateral half of this process is then removed, and the quadratus lumborum and psoas are carefully separated from the vertebra, which is thus exposed. Care must be taken not to damage the lumbar nerves in the region of the intervertebral foramina.

**Osteogenic Sarcoma.** Dr. Mark B. Coventry[12] and Dr. David C. Dahlin[13], in a review of the bone tumors seen at the Mayo Clinic from 1909 through 1955, reported a series of 2,276 pathologically verified neoplasms. The classification had included myeloma, of which there were 663 cases. The most frequent other varieties were osteogenic sarcoma (490), chondrosarcoma (218), Ewing's tumor (141), reticulum-cell sarcoma (70), and fibrosarcoma of bone (58).

The report dealt with osteogenic sarcoma. The authors described this lesion as a malignant tumor of bone with proliferating neoplastic cells which produce osteoid. Tumors so classified had been found to have a similar age distribution, a similar localization, and a similar strong tendency to metastasize. These osteoid-producing tumors were divided into three groups on the basis of the predominant tissue: the osteoblastic type (50 per cent), the chondroblastic type (27 per cent), and the fibroblastic type (23 per cent). Twenty-one osteogenic sarcomata located on the outer surface of the periosteum, nineteen located on the mandible, and twenty located on the maxilla had been excluded, which had left 430 cases for study. It was stated that 97 per cent of the 430 patients had been traced and follow-up data on these patients had been available. In 50 per cent the tumors had been located about the knee, while in only eight the hands or feet had been involved. Forty-seven per cent of the patients were ten to nineteen years of age. Treatment of the tumors had consisted mainly in amputation, local resection, and x-ray therapy, the latter being done either in conjunction with surgery or alone. In a few patients nothing more than biopsy had been done. X-ray therapy alone had been the definitive form of treatment in one-fifth of the patients and, in a few instances, had resulted in long survival.

[9] 2627 East Washington Street, Pasadena, California.
[10] Johns Hopkins Hospital, Baltimore, Maryland.
[11] 601 North Broadway, Baltimore, Maryland.
[12] 102–110 Second Avenue S.W., Rochester, Minnesota.
[13] 102–110 Second Avenue S.W., Rochester, Minnesota.

In the total series, a five-year survival from the time of treatment had been obtained in 19 per cent of the 353 patients treated before 1951 who had been traced and a ten-year survival had been obtained in 15 per cent of the 294 patients treated before 1946 who had been traced. The survival rate was influenced by the degree of differentiation and the location of the tumor. In the series of thirty cases in which the innominate bone was involved, there were no five-year survivals; while in the series of seventy-eight cases in which the tibia was involved, there was a five-year survival rate of 34.6 per cent. As regards the different types of tumor, the five-year survival rate was 15.8 per cent for the osteoblastic type, 28.8 per cent for the fibroblastic type, and 35.2 per cent for the chondroblastic type. The most significant finding in this study was the five-year survival rate of almost 20 per cent in the osteogenic sarcoma series. It was felt that the most effective form of treatment of osteogenic sarcoma is surgical ablation. When possible in this procedure, two tourniquets had been placed on either side of the operative site. In most cases the diagnosis had been confirmed by study of fresh frozen sections; in the others, by the regular "fixed" method.

**Aims, Programs, and Achievements of the National Foundation for Infantile Paralysis.** Dr. Kenneth S. Landauer [14] presented a brief report of the present vaccine program of the National Foundation for Infantile Paralysis. It was estimated that a 50 per cent reduction in paralytic involvement from this disease can be expected during the year 1956. He stated that more and more vaccine is becoming available and that in due time still better control of the disease can be expected. He also estimated, however, that at present there remain over 60,000 patients with severe involvement for many of whom modern rehabilitation techniques have much to offer. Considerable further treatment must be given in this group and, therefore, the work of the National Foundation for Infantile Paralysis is by no means complete. Dr. Landauer cited the achievements of the National Foundation's fifteen Respiratory and Rehabilitation Centers in the rehabilitation of respiratory and quadriplegic poliomyelitis patients as a demonstration of what can be accomplished by a team approach to comprehensive patient care. He stated that the National Foundation is extremely interested in aiding worthy research and that it would be happy to consider any project concerning unsolved problems in poliomyelitis.

**Experience in Reconstructive Surgery with Patients Having Respiratory Paralysis.** Dr. Vernon L. Nickel [15] and Dr. Wiley L. Renshaw [16] stated that the lives of an increasing number of patients with respiratory paralysis are being saved because of revolutionary improvements in their mechanical and

Vital Capacity

| (*Per cent*) | March 1954 to March 1955 | March 1955 to March 1956 |
|---|---|---|
| 0 to 10 | 0 | 5 |
| 10 to 20 | 0 | 5 |
| 20 to 30 | 0 | 29 |
| 30 to 40 | 2 | 15 |
| 40 to 50 | 2 | 17 |
| 50 to 60 | 5 | 18 |
| 60 to 70 | 8 | 9 |
| 70 to 80 | 14 | 16 |
| 80 to 90 | 13 | 17 |
| 90 to 100 | 25 | 33 |
| Total Surgery | 69 | 164 |

medical care. The authors also stated, however, that many of these patients are being denied the advantages of reconstructive surgery because of the increased hazard this surgery presents. This is particularly unfortunate because in the severely involved patient one or two elective operative procedures may significantly increase function. Furthermore, spine fusion in a patient with a progressive scoliosis or a severely paralyzed collapsing torso may actually prolong life.

At the Rancho Los Amigos Respiratory Center for Poliomyelitis, from March 1954 to March 1956, 233 orthopaedic operations had been performed, sixty-nine during the first year and 164 during the second year. The table shows the percentage of normal vital capacity possessed by the patients at the time of surgery. It is clear from this table that the surgical risk in the patients operated upon the second year was greater than that in the patients operated upon the first year. The improvement in the treatment of

[14] 120 Broadway, New York, N. Y.
[15] 1216 Wilshire Boulevard, Los Angeles, California.
[16] Los Angeles County Hospital, Los Angeles, California.

severe bulbo-spinal poliomyelitis in recent years has presented the surgeon with a considerable number of patients who heretofore would have been denied the advantages of reconstructive surgery. The respirator which originally saved the patient's life now permits this patient to undergo operation. In the authors' series there were no serious complications or deaths during or following surgery.

**Treatment of Volkmann's Contracture by Excision of the Infarct.** MR. H. J. SEDDON [17] reported that the primary concepts derived from an examination of sixteen patients was that the area of ischaemia is an ellipsoid, the axis of which is roughly parallel to the line of the anterior interosseous artery and that the damage is greatest at the center of the ellipsoid and tapers off toward the periphery. The flexor digitorum profundus and the flexor pollicis longus are the most severely damaged structures. The proximal ends of the injured muscles may be spared, and the damage usually stops proximal to the wrist. The median nerve, being near the center of the damaged area, is more affected than the ulnar nerve, which is in the periphery.

There are three grades of muscle damage: reversible, which generally clears up in three months; serious fibrous contracture; and frank necrosis. There are also three grades of nerve damage.

In the first six cases treatment had not been attempted, but in the subsequent ten cases, the following procedures had been used, the result being fair restoration of function.

1. The infarct had been excised within a year of injury, the flexor digitorum profundus and flexor pollicis longus usually being included.

2. In patients with extensive damage, tendon transfers and arthrodesis of the wrist had been done.

3. If both nerves had been necrotic, the ulnar nerve had been used as a pedicle graft to repair the median nerve. Following this procedure good sensation had always been obtained. If the ulnar nerve had been fairly normal, it had been allowed to recover spontaneously. In such cases the ischaemic segment of the median nerve had been repaired by cable grafts.

The author stated that the correct timing of the different procedures had been a difficult problem. In his final program he had waited until at least three months after injury to perform the primary stage (in order to allow time for spontaneous recovery) but had never waited more than a year (after a year it might not be possible to fully correct the contracture). Included in the primary stage were lengthening or transference of the shortened but active tendons and repair of the damaged nerves. The author stated that wrist extensors should not be transferred until some months after the original contracture has been corrected so that the stretched muscles might regain their power, and that arthrodesis of the wrist should be done only as a terminal procedure.

Friday, June 22, 1956

**Arthrography of the Shoulder Joint.** DR. GRAHAM A. KERNWEIN [18] reported that contrast-media arthrography had been used to study shoulder conditions in ninety-six patients. In every instance the findings of this technique had been correlated with the findings of pain-obliteration and abduction-strength tests and, in fifty-four instances, they had also been correlated with the findings obtained at the time of operation.

The technique of arthrography is simple. Equal parts of 35 per cent diodrast and sterile water are mixed. This solution is then injected into the shoulder joint until either a definite resistance is met or a total of forty cubic centimeters has been inserted. In the author's series there had been no complications. Tissues removed at intervals of several days to over a year after injection had been indistinguishable microscopically from those taken from normal shoulders in which no diodrast had been used. The diodrast had completely disappeared from the shoulder within two to three hours, leaving no trace which could be detected roentgenographically.

The roentgenograms are easy to interpret, and in the author's series the findings had been confirmed at operation in fifty-two of the fifty-four patients treated surgically. The arthrographic picture of a normal adult shoulder has several distinguishing characteristics. The biceps synovial pouch, the subscapular bursa, the glenoid labrum, and the small pouch on the medial side of the humerus are all visualized. The capsule appears elastic and distensible, and its end is shown as a sharply defined line at the anatomical neck. Measurements made on the arthrogram reveal that the liquid-volume capacity is twenty cubic centimeters. A child's shoulder, as shown by arthrography, differs only in its liquid-volume capacity. If the arthrogram shows alteration in the elasticity of the capsule, an abnormal extra-articular communication, or a significant alteration in the liquid-volume capacity, the presence of an abnormal condition should be suspected.

The active and passive ranges of motion and the abduction strength of the shoulder are evaluated only after pain has been obliterated with the aid of a local anaesthetic. Among the twenty-one patients in the author's series with a normal range of motion and strength, three had been found to have incomplete tears of the rotator cuff. Of forty-three patients with normal passive and active ranges of motion but weakened abduction strength, thirty-seven had been found to have arthrographic evidence of a ruptured rotator cuff. Of eleven patients with loss of active-abduction range and strength but with a normal passive range of motion, only two had been found who did not have a ruptured rotator cuff.

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[18] 303 North Main Street, Rockford, Illinois.

Reduced active and passive ranges of motion and reduced abduction strength are characteristic of capsulitis. The author's arthrographic studies had revealed that in patients with capsulitis a joint space is universally present, the capsule is inelastic and non-distensible, and the liquid-volume capacity is reduced to less than half of normal. No abnormal extra-articular communications had been found.

The author presented arthrograms of normal joints and of joints with the following conditions: uncomplicated complete or incomplete rupture of the rotator cuff, rupture of the rotator cuff associated with complete or incomplete dislocation of the tendon of the long head of the biceps brachii, rupture of the tendon of the long head of the biceps brachii, calcification of the supraspinatus, dislocation and subluxation of the scapulohumeral joint, and capsulitis.

**Problems of Soft-Tissue Calcification as Related to Orthopaedic Surgery.** Dr. H. R. McCarroll[19] presented a discussion of heterotopic bone formation and calcification in soft tissues. He mentioned some of the outstanding articles on this subject and emphasized the significance of soft-tissue calcification and heterotopic-bone formation in many of the typical problems seen by the orthopaedic surgeon. True ossification or new-bone formation usually occurs by means of direct extension of osteogenic cells (as from a torn periosteum) into a neighboring hematoma. Ossification in soft tissues which are not in direct continuity with or proximity to bone occurs as a result of an induction process which is presumably due to metaplasia of the surrounding connective-tissue cells. Instances of such ossification have been found in the fibrous tissue capsule which surrounds a traumatic cyst filled with old blood; in the abdominal wall following surgery; in the presence of venous stasis; in the ovary; in uterine fibroids; and in tissues adjacent to calcified tubercules, atheromatous plaques, and renal calculi. Soft-tissue calcification has also been found in scleroderma, in periarteritis nodosa, and beneath deep surface scars in third-degree burns. The process by which heterotopic bone is formed in soft tissues is not clearly understood.

The author classified amorphous calcification in soft tissues according to etiology, the different types being the congenital, the infectious, the neoplastic, and the traumatic or degenerative. Accurate classification, he stated, may be difficult or impossible.

In the author's series, observations of soft-tissue calcification in relation to the subdeltoid bursa and supraspinatus tendon showed that in fluid aspirated early in the process (within a few hours) the calcium content may be as low as seven milligrams per 100 cubic centimeters. In one case, when the fluid was aspirated later (within three days), the calcium content was found to be fifty-three milligrams per 100 cubic centimeters. When the fluid is aspirated after a week, it may be very thick and in one patient the calcium content was found to be 366 milligrams per 100 cubic centimeters. As the calcium content rises, so also does the white-blood-cell content and the cell-detritus content. Gradually the material in which the calcification occurs changes from a fluid into a material composed of granules of sand-like material which have the characteristics of calcium apatite. These deposits of calcified soft tissues are often absorbed later—a process which may be accelerated by diathermy, roentgenotherapy, or the use of hydrocortisone. When conservative measures fail, surgical excision may be justified.

**A Study of Bone Replacement.** Dr. Robert D. Ray[20] reported a series of experiments designed to study the rate of healing of standard bone defects following implantation of (a) frozen intact homogenous bone, (b) deproteinized homogenous bone, and (c) decalcified homogenous bone. In these experiments defects had been made by means of a standard trephine in the parietal bones of rats. The rats had then been divided into three groups, and in each group the defects had been filled with fragments of homogenous fibular bone prepared according to one of the three methods mentioned above. Six weeks after implantation the defects had been studied roentgenographically and histologically. The following findings had been observed.

1. Roentgenograms showed that in sixteen of the eighteen rats in which frozen homogenous bone had been used, there was minimal bone proliferation. In the other two animals in this group the defects were about one-third filled by new bone. The margins of some of the implants were covered with new bone, but there was minimal or no invasion and incorporation of the implant material. Foreign-body reaction was present.

2. In the defects in which deproteinized bone had been implanted, there was likewise roentgenographic evidence of minimal new-bone formation. Histologically, there appeared to be minimal or no incorporation of the implant. Foreign-body reaction was occasionally present.

3. Of the twelve animals in which the defects had been filled with decalcified homogenous bone, five showed complete bridging. In two other animals the defects were two-thirds filled, in four others they were one-third filled, and in one there was minimal repair. Histological study showed that the implants were well incorporated into the host bone and that there was little or no foreign-body reaction.

The authors concluded that of the materials used, decalcified organic matrix had been replaced by host

[19] 3720 Washington Boulevard, St. Louis, Missouri.
[20] University of Illinois, College of Medicine, Chicago, Illinois.

bone the most rapidly and that the presence of inorganic salts in the implants had impeded the process of replacement.

**The Function of Bone in Calcium and Phosphorus Regulation.** DR. D. HAROLD COPP [21] stressed the importance of bone as a reservoir of minerals and pointed out that over 99 per cent of the total amount of calcium in the body, as well as 90 per cent of the phosphorus, is contained in the skeleton. He also pointed out that although the calcium in the blood represents a small fraction of the total amount of calcium in the body, its level is remarkably stable—in spite of continual loss of calcium in the feces, urine, and sweat, continual intake of calcium in the diet, and continual fluctuations in the formation and resorption of bone.

In the first series of experiments reported by the author, the level of serum calcium in dogs had been lowered by the constant intravenous infusion of a calcium complexing agent (versene). After the infusion had been discontinued, the rate of calcium mobilization had been determined as the level of the calcium in the blood returned to normal. The rate of mobilization had been found to bear a linear relationship to the degree to which the serum calcium level had been depressed. On the basis of these experimentally determined values for the rate of calcium mobilization and on the basis of the assumption that the blood-calcium level is restored to normal when blood flows through bone, the author had estimated that the total blood flow through the skeleton must represent at least 5 per cent of the total cardiac output.

In a second series of experiments reported by the author, rats had been placed on a diet which was low in phosphorus. Balance studies had revealed that while the animals had lost only minute amounts of phosphorus, they had lost tremendous amounts of calcium. Analysis of the tissues at autopsy had revealed that the soft tissues had retained a normal phosphorus content but that the level of phosphate in bone was only one-fifth of that in the control animals. This finding indicated that there had been a diversion of phosphorus from the skeleton to the soft tissues. Demineralization of the skeleton (but not of the teeth) had been confirmed by roentgenograms. From these experiments, the author had concluded that the role of the skeleton in regulating the levels of calcium and phosphorus in the body may, under stress, even jeopardize the structural integrity of the skeleton itself.

Saturday, June 23, 1956

**The Treatment of Slipped Femoral Epiphysis by Gentle Manipulation and Bilateral Leg Casts.** DR. J. HIRAM KITE [22] called attention to the fact that the chief cause of bad results following treatment of slipped capital femoral epiphyses is necrosis of the femoral head, not deformity. He had observed that treated patients, in whom necrosis often develops, frequently have more disability than do untreated patients, in whom necrosis seldom develops. He believed that treatment may be the cause of the necrosis and that, in this relatively rare condition, the end result depends more on the stage at which treatment is begun than on the type of treatment which is used. In his group practice, an average of only two cases are seen each year (0.043 per cent of the total number of patients seen).

The analysis included sixty-eight patients with eighty-one involved hips. Most of the patients had been treated by manipulation and the application of casts—a hip spica having been used in the earlier cases in the series and a double toe-to-groin cast having been used in the later cases. As experience had been gained, it had been found that it was better to accept imperfect reduction than to do forceful traumatic manipulation. In the final form of treatment used by the author, complete relaxation had been obtained with the patient under general anaesthesia, following which Ledbetter manipulation had been gently done on the hip (as is done for subcapital fracture). Bilateral toe-to-groin casts had then been applied, the involved limb being completely, but not forcibly, internally rotated and abducted and the normal limb being placed in a position of neutral rotation and mild abduction. A stick had been placed across the feet in order to hold the limbs in this position. The author presented nine cases in which this method of treatment had been used; in seven good results had been obtained, but in the remaining two some aseptic necrosis and stiffness of the hip had developed. The author felt that this method is the treatment of choice and stated that it had been particularly successful in the patients treated early.

**Slipped Femoral Epiphysis with Severe Displacement. A Conservative Operative Treatment.** DR. CLARENCE H. HEYMAN [23] reported an operation designed to remove the ridge which remains on the anterolateral aspect of the neck of the femur following slipping of the capital femoral epiphysis. By this operation, limitation of internal rotation and abduction can be eliminated. In the author's series twenty-one operations had been done upon twenty patients, the condition in one patient being bilateral. Following the operation the spiral flexion of the hip usually seen in patients with slipped femoral epiphyses had disappeared and the patient's gait had been greatly improved, becoming even normal in some. The author

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[22] 490 Peachtree Street N.E., Atlanta, Georgia.
[23] 10515 Carnegie Avenue, Cleveland, Ohio.

discussed the difficulty of accurately estimating improvement in the patient's range of motion and stated that it was expected, not that limp should be completely removed, but that it would be considerably reduced. In his series there had been no instances of aseptic necrosis of the femoral head following the operation. He felt that at least two years of follow-up was required and stated that in most of his cases the follow-up had been much longer. The first patient had been operated upon in 1935.

**Prosthetic Replacement of the Femoral Head.** Dr. Frank E. Stinchfield [24], Dr. Bernard Cooperman [25], and Dr. Cyril E. Shea [26] presented their experiences with the use of Austin Moore and Judet prostheses in the upper end of the femur in 147 patients. One hundred and five of these patients had been available for study. Of these fifty-five had a Judet prosthesis and fifty had the Austin Moore type. The ages of the patients ranged from twenty-three to ninety years, the average age being sixty-three. At the time of study, the patients had been followed for one to five years.

The results were graded according to the method of Judet, and the authors had used the terms *excellent, good, fair,* and *poor*. For convenience, the patients were divided into groups on the basis of their local pathological condition. (1) Forty-four patients had had fresh fractures of the femoral neck. Twenty-one of these patients could not be included in the study, however, because they were unavailable for personal examination. Of the remaining twenty-three, nine had Judet prostheses and fourteen had Austin Moore prostheses. The results in the patients with the Austin Moore prostheses were slightly better than those in the patients with the Judet prostheses. (2) Sixteen patients with avascular necrosis had been treated, fifteen by the Judet prosthesis and one by the Austin Moore type. The average age was sixty-two years, and the average length of follow-up three years. All the results were classified as *good*. (3) Twenty-three patients with non-union of the femoral neck (average age, sixty-two) had been treated, eight by the Judet type and fifteen by the Austin Moore type. It was felt that the group with the Austin Moore prosthesis had better results. (4) There were forty-three patients with osteo-arthritis of the hip, the average age of these patients being fifty-four years. In these, twenty-three Judet and twenty Austin Moore prostheses had been used, with slightly better results in the group with the Judet prosthesis. Of the total series of 105 patients, 28 per cent were able to walk without support and another 42 per cent had to use only one cane. An over-all good or excellent result was ascribed to 68 per cent of the patients.

The type of incision used influenced the results in that the patients in whom a Gibson approach had been used did not walk as well as those in whom a Smith-Petersen approach had been used. No difference was noted between those with repair of the capsule and those with complete capsulectomy. Reaming of the acetabulum had definitely had an adverse effect, as only 38 per cent of the patients in whom this had been done were considered to have excellent or good results. Some form of postoperative immobilization had been used in all of the patients except those with fresh fractures; the period of immobilization had ranged from seven to twenty-one days. Complications had included: dislocation, five; fracture of the femur, three; infection, two; cardiac arrest, one; non-fatal pulmonary infarct, five; loosening of the stem of the Judet prosthesis requiring replacement, eight; and protrusion of the stem of the Austin Moore prosthesis, two. There were five postoperative deaths. It is worthy of note that the twelve patients treated by anticoagulants for phlebitis obtained a better range of motion than did the others.

From this study the authors have concluded that (1) for fresh fractures in the aged, the Austin Moore prosthesis may sometimes be the best form of therapy; (2) in the presence of non-union and a viable femoral head, an attempt at osteosynthesis should be made; (3) in the presence of avascular necrosis, a prosthesis may be the best available therapy; (4) for osteo-arthritis of the hip, a prosthesis gives results which compare with those obtained by a Smith-Petersen mold, but which are inferior to those obtained by arthrodesis, when this is feasible. When the prosthesis fails, perhaps the best salvage procedure is to remove it; the patients in the authors' series in whom this was necessary did surprisingly well.

**Results in Mold Arthroplasty.** Dr. Otto E. Aufranc [27] reported a study of Vitallium-mold arthroplasty. The cases of 1,000 patients treated by this method over a period of eighteen years had been reviewed. In over 200 of these patients the operation had been performed bilaterally, and 225 of the patients had received supplemental surgery. In the total series, the results had been excellent in forty-five, good in 175, satisfactory in 600, and unsatisfactory in 180. Four hundred and sixty patients had been enthusiastic and 360 had been satisfied, while 100 had been noncommittal and eighty had been dissatisfied. The group of 460 enthusiastic patients included all of those with excellent results, 66 per cent of those with good results, 46 per cent of those with satisfactory results, and 16 per cent of those with unsatisfactory results. The satisfied group included 31 per cent of the patients with good results, 36 per cent of those with satisfactory results, and 46 per cent of those with unsatisfactory results.

[24] 180 Fort Washington Avenue, New York, N. Y.
[25] Presbyterian Hospital, New York, N. Y.
[26] Presbyterian Hospital, New York, N. Y.
[27] 266 Beacon Street, Boston, Massachusetts.

Forty-three operations had been complicated by sepsis, and three patients had died. Other complications had been: thrombophlebitis, fifty cases; pulmonary emboli, thirty-seven; subluxation, sixteen; dislocation, four; transient peroneal palsy, one; permanent peroneal palsy, one; fracture of the neck of the femur, three; fracture of the shaft, two; and infectious hepatitis, two. There had been no pain in 22 per cent, slight pain in 31 per cent, moderate pain in 29 per cent, pain most of the time in 17 per cent, and pain all the time in 8 per cent. Infections had developed in eight patients with rheumatoid arthritis, in thirteen with old aseptic arthritis, in seven with infected old fractures, in ten with tuberculosis, and in five with miscellaneous conditions. In twelve patients the cups had been removed. Revision or exploratory surgery had been done in 36 per cent of the patients with rheumatoid arthritis, in 30 per cent of those with old sepsis, in 22 per cent of those with congenital hip conditions, in 14 per cent of those with old fracture of the neck of the femur, in 47 per cent of those with malum coxae senilis, and in 8 per cent of those with fracture-dislocation. Thirty-three per cent of the patients with single-hip conditions and 25 per cent of those with bilateral conditions required no support. Sixty per cent of those with single-hip conditions and 25 per cent of those with bilateral conditions needed canes or crutches part of the time, while 27 per cent of the former and 50 per cent of the latter needed them all of the time. Fifty per cent of the patients with single-hip conditions could walk up to one mile.

In summary, the author felt that in 820 cases the results had been excellent, good, or satisfactory, while in 180 cases they had been unsatisfactory. He stated that mold arthroplasty is a sound surgical procedure if it is properly applied and that good-to-excellent results would be more frequent if the patients were always managed according to sound principles of bone healing and muscular control. Absorption of the head and shortening of the femoral neck under the mold had occurred in his series but had not been much of a problem; in fact, he had had difficulty in finding ten instances of these complications. The author felt that the greater range of motion, decrease in pain, and greater stability that can be obtained at present are the result of better instruments and operative technique, better understanding of convalescent care, and improvements in the design of the mold.

## THE RUSSELL A. HIBBS SOCIETY

As Reported by N. J. Giannestras, M.D., *Secretary-Treasurer*, Cincinnati, Ohio

The Ninth Annual Meeting of The Russell A. Hibbs Society was held on Friday, May 4, 1956, at the University Hospital, Ohio State University, Columbus, Ohio, under the presidency of Dr. Judson D. Wilson.

Dr. Wilson appointed Dr. Frank E. Stinchfield (Chairman), Dr. Neill Garber, and Dr. Herbert Pedersen as members of a committee to look into the proper dispensing of The Society's funds and to make a report at the next meeting.

The following men were unanimously elected to membership:

Dr. Stanley Atkins, Asheville, North Carolina;
Dr. Cline D. Hensley, Jr., Wichita, Kansas;
Dr. Richard H. Kiene, Kansas City, Missouri;
Dr. William R. MacAusland, Jr., Boston, Massachusetts;
Dr. Daniel C. Riordan, New Orleans, Louisiana;
Dr. D. Keith McElroy, New York, N. Y.

Dr. Frank E. Stinchfield, New York, N. Y., was elected President of the Society for the ensuing year, and Dr. Nicholas J. Giannestras was re-elected Secretary-Treasurer. The next meeting will take place at the New York Dispensary and Hospital, New York, N. Y., in commemoration of the tenth anniversary of the founding of The Russell A. Hibbs Society.

**Posterior Osteotomy for Ankylosing Arthritis of the Spine.** Dr. Clyde W. Dawson [1] described his procedure, which he had performed upon four patients and which had been found to be satisfactory. The patient is placed in the prone position on the table, which is fully flexed. Intratracheal anaesthesia is given and the incision is made. The spinous processes of the third, fourth, and fifth lumbar vertebrae are then identified. The entire lamina of the fourth lumbar vertebra is removed, care being taken not to injure the dura mater or the underlying nerve roots. Subsequently the inferior articular processes of the fourth lumbar vertebra, the superior articular processes of the fifth lumbar vertebra, and the pedicle of the fourth lumbar vertebra are resected. Spontaneous correction occurs as soon as this resection has been done. The table is then gradually made level. Since spontaneous correction takes place, no manipulation of the spine is necessary. The operation is done at the level of the fourth lumbar vertebra because at this level there is no possibility of damage to the spinal cord, the cauda equina beginning at the level of the first lumbar vertebra. Following complete correction, the spinous process of the third lumbar vertebra is wired at its base to the spinous process of the fifth lumbar vertebra, thus preventing any possible anterior displacement of the vertebral bodies. No bone-grafting is necessary, for the defect is rapidly filled with bone. Following closure of the wound, the patient is kept in a plaster shell for eight weeks. A Taylor brace is then worn for a period of one year. The medical regimen is continued under the constant supervision of the rheumatologist.

The only contra-indication to this operative procedure is calcification of the aorta. The results in the one case presented as an illustration were excellent. The patient was pleased and stated that he was able to go hunting which he had been unable to do previously.

**Case Presentations.** Dr. Judson D. Wilson [2] presented the cases of eleven adults in whom non-union of the clavicle had resulted following fracture. These patients had been treated by resection, the amount of clavicle resected extending approximately three to four centimeters on either side of the fracture site. The patients had been able to return to work an average of two weeks after operation. They had no weakness of the shoulder, but they did have a slight deformity consisting of a mild depression of the soft tissues over the resected site. Dr. Wilson described several patients who were satisfied with the result, the function of the shoulder being good and the cosmetic appearance being satisfactory.

Dr. Wilson also presented a follow-up study of twenty patients with hallux valgus in whom the McKeever arthrodesis had been done. As a part of the post-operative care of these patients, a transverse bar had been placed on the sole of the shoe well behind the region of the metatarsal heads. This bar had elevated the foot in order to prevent any weight-bearing in the metatarsal region, all weight-bearing being shifted to the heel. The toe of the shoe had been cut out. The patients had been permitted to begin normal weight-bearing after two weeks. The follow-up in this series had been adequate, and the fusion had been successful in all twenty patients.

In conclusion Dr. Wilson presented the cases of eight patients in whom a prosthesis had been inserted in the lower end of the humerus following resection of the elbow due to severe injury. The results had been satisfactory in adults, particularly in those in whom a previous resection had been performed because of limitation of motion and because of the patient's dissatisfaction with his flail elbow. The same procedure had been tried in four younger patients, two of whom had rheumatoid arthritis and two of whom had traumatic arthritis of the elbow. In all four the results had been poor because of bone regeneration. The type of prosthesis used in this series was a Vitallium mold. A posterior approach had been used, and an attempt had been made to maintain the integrity of the capsule in order to anchor it to the prosthesis following insertion. In the one patient in whom this maneuver had not been done, the ulna and radius had dislocated posteriorly on the prosthesis. In every patient, the ulnar nerve had been isolated. The results, as demonstrated in three patients, had been impressive. Each individual had a stable range of motion at the elbow of at least 90 degrees, with little or no pain, and each was highly pleased with the result.

During the discussion, Dr. Frank E. Stinchfield [3] suggested the use of an anticoagulant to inhibit bone formation. He stated that patients in his care had been given such medication for a period of up to eight weeks, the prothrombin level being maintained at between 35 and 38 per cent.

**Unsuspected Spondylitis in Children.** Dr. F. W. McCoy [4] drew attention to the presence of fusion of the apophyseal joints of the cervical spine in juvenile patients with rheumatoid arthritis. This condition had first been reported by Barkin at the June 1954 meeting of the American Rheumatism Association. For some time thereafter it had been felt that its occurrence in children was relatively rare. A review of the author's series, however, had revealed that among twenty-three patients with rheumatoid arthritis, thirteen had fusion or spondylitis of the cervical vertebrae, the condition originating between the second and third cervical vertebrae and extending distally. Roentgenograms had demonstrated that in five of these thirteen patients the

[1] 150 East Broad Street, Columbus 15, Ohio
[2] 1401 South Hope Street, Los Angeles 15, California
[3] 180 Fort Washington Avenue, New York 32, N. Y.
[4] Hospital for Special Surgery, New York 17, N. Y.

changes in the sacro-iliac joints were indistinguishable from the type of change seen in adults with spondylitis. There was no unusual sex difference in this series, and the degree of involvement did not appear to be necessarily related to the severity of the arthritis, being apparently more related to the length of time the patient had suffered from polyarthritis. The author presented the following conclusions: (1) Roentgenograms should be made of the cervical spines of all children with rheumatoid arthritis of the peripheal joints. (2) Repeat roentgenograms should be made frequently. (3) The initial site of involvement is between the second and third cervical vertebrae, progressive changes appearing thereafter in the other cervical vertebrae. It is not known if the sacro-iliac involvement is a similar process or if the two are related. (4) This condition never occurs alone but is always found in association with active rheumatoid arthritis.

**The Hand as a Guide in the Radiologic Diagnosis of Osseous Manifestations of Certain Systemic Diseases.** Dr. Sidney W. Nelson [5] described the changes which may be seen, by means of roentgenograms, in the involved hands of patients with hyperparathyroidism, renal osteodystrophy, rickets, scurvy, gout, sarcoidosis, sickle-cell anaemia, secondary hypertrophic pulmonary osteo-arthropathy, and tuberous sclerosis.

**Bone Overgrowth and Calcium Storage Depots in the Parakeet.** Dr. Hans G. Schlumberger [6] stated that in normal female parakeets, as in the females of several other species of birds, large amounts of new bone are deposited in the medullary cavity of the femora just before the egg-laying period. This deposit may serve as a storage depot for the calcium needed in shell production. The authors had examined seventeen female birds in which a tumor-like overgrowth of cortical bone had been found involving several of the following regions: sternum, sacrum, vertebrae, ribs, skull, humeri, femora, and even the hyoid bone. In some, the diameter of the mass had reached two centimeters and grossly the masses resembled tumors. Histopathologically there was evidence of new-bone formation, with prominent osteoblasts and occasional osteoclasts. The condition somewhat resembled Paget's disease or fibrous dysplasia in man. The author stated that exophthalmos may arise from the orbital plate as a result of the bone masses and that paralysis of an extremity as a result of pressure on the nerve at an intervertebral foramen had been observed.

Similar changes had not been found in male birds. When large doses of estrogen had been administered to these birds, however, overgrowths resembling those in the females had been produced. In two male birds in which these changes had been demonstrated roentgenographically, the serum calcium level had been 35.3 and 75.5 milligrams per 100 cubic centimeters. The normal level is five to eight milligrams per 100 cubic centimeters.

**Bone Changes in Multiple Myeloma.** Dr. Thomas J. Klug [7] and Dr. William S. Smith [8] had reviewed fifty-eight proved cases of multiple myeloma, carefully examining the roentgenograms in order to determine the changes present at the time of diagnosis. In general the most common findings in patients with multiple myeloma are generalized osteoporosis, pathological fracture, and osteolytic lesions. In the authors' series the most common finding had been osteoporosis and osteolytic lesions in combination. This had been found in thirty-one of the fifty-eight patients. Osteoporosis alone had been found in twenty others, osteolytic lesions alone in four, and neither osteoporosis or lytic lesions in thirteen. Since 30 per cent of the patients in this series had first been seen because of back pain, the authors had attempted to classify the spinal changes shown by the roentgenograms. Seven categories had been selected, the three largest being: osteoporosis alone, twenty cases; neither osteolytic lesions nor osteoporosis, fifteen cases; and osteoporosis associated with one or more compression fractures, eleven cases. In conclusion the authors stated that the presence of the triad of anaemia, back pain, and osteoporosis indicates a diagnosis of multiple myeloma.

**Paper-Strip Electrophoresis in the Diagnosis of Multiple Myeloma.** Dr. Robert L. Wall [9] presented a step-by-step discussion of the technique of paper-strip electrophoresis and demonstrated a number of representative patterns found in patients with multiple myeloma.

Other papers presented were:

**The Effect of Tension Across the Epiphyseal Plate.** Dr. William S. Smith [8] and Dr. James B. Cunningham [10].

**Scalenus Anticus Syndrome Associated with Cervical-Disc Pathology.** Dr. Harry E. LeFever [11].

**The Role of Potassium in the Surgical Patient.** Dr. Robert N. Watman [12].

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[7] Ohio State University Hospital, Columbus 10, Ohio
[8] 196 East State Street, Columbus 15, Ohio
[9] Ohio State University Hospital, Columbus 10, Ohio
[10] Barnes Hospital, St. Louis 10, Missouri
[11] 1275 Olentangy River Road, Columbus 8, Ohio
[12] Ohio State University Hospital, Columbus 10, Ohio

## PIEDMONT ORTHOPAEDIC SOCIETY

As Reported by John P. Adams, M.D., Washington, D. C.

The Piedmont Orthopaedic Society held its Annual Meeting at the Cloister Hotel, Sea Island, Georgia, on May 25 to 27, 1956, under the chairmanship of Dr. Jack C. Hughston.

Elected to office for the coming year were:

*Chairman:* Dr. Robert A. Knight, Memphis, Tennessee;
*Secretary-Treasurer:* Dr. J. Leonard Goldner, Durham, North Carolina;
*Recording-Secretary:* Dr. John P. Adams, Washington, D. C.

Friday, May 25, 1956

**Coxa Plana in Congenital Dislocation of the Hip.** Dr. Garry DeN. Hough, III [1] reported that in 167 unselected cases of congenital dislocation of the hip, coxa plana had been found in 38 per cent and changes of an intermediate nature in an additional 29 per cent. In this series the incidence of coxa plana had appeared to be closely related to the size of the ossification center of the femoral head at the time of primary reduction. This complication had been especially prevalent in those hips in which reduction had preceded ossification. The correlation of the incidence of coxa plana with sex or with the presence of contralateral dysplasia, dislocation, or other congenital anomalies was negligible; and if the figures were weighted for the presence of an ossification center in the epiphysis, there was no correlation. A higher incidence had been noted in patients treated by closed methods as opposed to open reduction and in patients treated when under the age of two years. This difference could be partly, but not completely, explained by variations in the size of the capital femoral epiphysis. The author stated that the development of coxa plana in patients with congenital dislocation of the hip who have undergone treatment cannot be fully explained on the basis of inadequacy of blood supply.

**Internal Fixation of Fractures of the Carpal Navicular.** Dr. Clifford A. Stevenson [2] reported a series of fractures of the carpus scaphoid in which a threaded Kirschner wire had been used as the internal-fixation device. In fifteen of the patients there had been non-union, in three there had been fresh unstable fracture, and in one there had been delayed union. Union had been obtained in the patients with fresh fracture and delayed union and in one of the patients with non-union. In most of the other patients with non-union some relief of pain had been obtained, but in four the result had been failure.

**Recurrent Giant-Cell Tumor of the Femoral Condyle Replaced by a Massive Graft.** Dr. Harold H. Kuhn [3] presented a case in which the distal portion of the femur had been resected for recurrent giant-cell tumor and the resulting gap had been filled by a graft taken from the amputated femur of another patient. Arthrodesis of the knee had been performed at the same operation.

**Peritendinonitis Calcarea of the Hand and Wrist.** Dr. Cabell Young, Jr.[4], presented ten cases of calcification about the hand. The patients had been given roentgen therapy, the daily doses varying from fifty to 150 roentgens and the maximum dose being 450 roentgens. This therapy had been effective in all patients. In patients with the acute type the response had been immediate, with considerable relief from pain within twenty-four to forty-eight hours. In patients with the subacute or chronic type, relief from pain had been obtained in four to seven days. Regression of erythema and soft-tissue swelling had been rapid in the patients with the acute type and slightly prolonged in the others. Restoration of full function had also been rapid in the former group but had been delayed in the latter.

Following the institution of radiation therapy the roentgenograms had demonstrated a prompt change in the character of the calcium deposit, and complete absorption had occurred in almost all patients.

**Report of Two Cases of Lower-Extremity Injury.** Dr. Julian E. Jacobs [5] presented a case in which a patellar transplant had been used to replace a severely damaged tibial condyle. Five years after operation, the function of the leg was satisfactory. The patient was working twelve hours daily, could climb stairs, and did not complain of pain.

In the second case presented by Dr. Jacobs, the lesion involved the foot. The initial roentgenograms had been interpreted as not revealing a fracture. Because of persistent pain about the heel, however, further

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[2] United States Naval Hospital, Portsmouth, Virginia
[3] 1109 Quarrier, Charleston, West Virginia
[4] Bowman Gray School of Medicine, Winston-Salem, North Carolina
[5] 123 West Seventh Street, Charlotte, North Carolina

roentgenograms had been made and a fracture of the peripheral portion of the calcaneus had been discovered. This fracture still could not be identified on the initial roentgenograms. Four similar cases had been reported to the author by colleagues.

**Dislocations of the Elbow without Fracture.** Dr. John A. Powers [6] reported that the best method of obtaining reduction of elbow dislocation is to place the arm in traction with the elbow flexed to 90 degrees and the forearm in a position of mid-pronation-supination in order to relax the pronator teres. In all of the eighteen patients in his series reduction had been obtained without the elbow being hyperextended, a maneuver which tends to damage further the brachialis and to cause myositis ossificans.

The author reported that follow-ups of at least a year had revealed that the results in the nine patients not immobilized in a cast were significantly better than those in the nine patients immobilized in a cast for two to four weeks. Full recovery had been noted within three months in patients in whom immediate active motion had been begun, the result being no residual stiffness in any direction. The author concluded that the ideal program after reduction is to support the elbow in a sling or compression bandage for twelve to seventy-two hours until the pain and swelling have subsided and then to start active motion without passively stretching or forcing the elbow.

**A Review of Severe Elbow Injuries.** Dr. Ralph W. Coonrad [7] had reviewed a series of 116 severe elbow injuries and had found the following results.

When T fractures and comminuted fractures of the lower portion of the humerus were simple and were treated early by open reduction, an almost normal range of motion was frequently obtained if motion was instituted within five to seven days after injury. If the fractures were immobilized two to four weeks before motion was begun, however, varying degrees of residual contracture resulted. In posterior dislocations of the elbow some residual contracture usually resulted if the arm was immobilized for two to four weeks. If motion was started after five to seven days or when the swelling had subsided, however, there was only minimal contracture, if any. In this series of 116 injuries, nine months to one year was considered the minimum adequate follow-up.

The problem of the poor mechanical advantage of the elbow flexors in the resected elbow was discussed, and it was suggested that the bone insertions of the biceps and brachialis should be transferred distally in the forearm, the tendons of these muscles being prolonged by means of free grafts. A preliminary report was presented of a patient in whom these muscles had been prolonged by means of a free sublimis graft inserted into the mid-shaft of the ulna. Sufficient stability had been achieved to enable this patient to move his arm from a position of horizontal full extension to a position of upward flexion of 90 degrees while holding a ten-pound weight. He was able to play baseball and comb his hair, and supported himself by driving a truck. Stability of the elbow during motions above the level of the shoulder was much improved.

**Femoral Shortening.** Dr. Leslie C. Meyer [8] stated that femoral shortening is still the simplest and most practical method of correcting lower-extremity length discrepancies after growth has been completed. He reported a series of sixteen patients, of an average age of fifteen years, seen at the Shriners' Hospital in Greenville, South Carolina. The average amount of shortening in these patients was one and seven-eighths inches, the maximum being two and a half inches and the minimum being one and a quarter inches. There had been no complications, and all the femoral fragments had united. The author reported that the operation found to be most successful was osteotomy combined with removal of a segment of the mid-shaft. In this operation the proximal and distal fragments had been drilled in order that an eleven-millimeter clover-leaf nail might be inserted without causing binding. The nails used had been sharp enough to penetrate easily the dense cancellous bone in the distal metaphyseal and epiphyseal areas. No postoperative immobilization had been used, and early quadriceps exercises had been carried out. The so-called trombone effect had been prevented by elevating the head of the bed, the patient's feet being firmly placed against a foot board. Union had been obtained in about three months, and all nails had been removed when union was complete.

**Osteochondrosis Deformans Tibiae, Tibia Vara, or Blount's Disease.** Dr. Herman A. Gailey, Jr.[9], stated that osteochondrosis deformans tibiae, tibia vara, or Blount's disease is characterized by a local disturbance in the growth of the proximal-medial portion of the tibia; as a result of this disturbance abrupt varus angulation develops. The remainder of the tibial shaft is straight and no femoral changes occur. The cause of this deformity is obscure. The process has been compared to Legg-Perthes disease and other types of osteochondrosis, but a more accurate comparison would be congenital coxa vara.

[6] 1500 Elizabeth Avenue, Charlotte, North Carolina
[7] Broad and Englewood Streets, Durham, North Carolina
[8] Medical Court, Greenville, South Carolina
[9] 1 Rathton Road, York, Pennsylvania

In a review of the literature the author had found two major series comprising approximately fifty cases; he had also found about twenty-five isolated reports, bringing the total number of reported cases to about seventy-five. Twenty-two new cases had been contributed by the membership of the Piedmont Orthopaedic Society, and after reviewing these cases the author had come to the following conclusions:

1. The disease is usually noted at the time the child begins to walk and is usually rapidly progressive, although regression and spontaneous correction may be seen.

2. The changes shown on the roentgenograms are diagnostic and typically include clear zones of irregular ossification, formation of a medial "beak", and abrupt angulation, this angulation progressing to severe depression of the medial tibial plateau.

3. Differentiation from bow-leg, rickets or refractory rickets, congenital bowing of the tibia, and other types of bow-leg is important.

4. In the later stages extreme instability of the knee is present and it is difficult to salvage a serviceable joint when treatment has been neglected.

5. Conservative treatment may be effective in the early stages.

6. Delay in surgical correction because of age or other considerations is a mistake and may result in irreparable damage; the incidence of recurrent deformity is greater when surgery has been delayed.

7. Factors causing recurrent deformity include delayed surgery, excessive instability of the knee, and inadequate correction at the time of surgery.

8. Osteotomy has proved to be a satisfactory procedure in many patients, and epiphyseal stapling has been utilized successfully in two patients.

## THE JAPANESE SOCIETY OF ORTHOPAEDIC SURGERY

The Twenty-eighth Annual Meeting of The Japanese Society of Orthopaedic Surgery (the Twenty-fifth Sectional Meeting of The Fourteenth Japan Medical Congress) was held at Kyoto University, April 2 through 5, 1955, under the Presidency of Dr. Eishi Kondo. Two foreign visitors, Dr. H. Junghanns from Germany and Dr. David M. Bosworth from the United States, presented addresses. This is the first time that the Society has invited foreign scholars to attend its Annual Meeting. Summaries of the papers presented during the Scientific Sessions follow.

**Treatment of Cerebral Palsy and Its Effect.** Dr. K. Takagi [1], in 1925, had advocated three methods of approach: (1) motivation of the patient to rehabilitate himself, (2) development of techniques to assist the patient in self-rehabilitation, and (3) use of exercises to promote self-rehabilitation. His present program of rehabilitation, established after thirty years of further experience, includes both medical aspects (psychological, physical, and surgical therapy) and social aspects (legislation and public education). Dr. Takagi has attempted to recondition the brain of the palsied patient by surgery and psychological treatment while at the same time carrying out surgical and physical therapy. The hospitals and institutions necessary for the treatment of this disease were classified by Dr. Takagi into three groups: (1) for mild cases, orthopaedic hospitals and special schools for crippled children; (2) for moderately severe cases, hospitals and convalescent homes; and (3) for severe cases, institutions for the care of the permanently disabled. Practical methods of self-rehabilitation instituted by Dr. Takagi include: (1) training in handwriting; (2) training in standing and walking; (3) guidance in daily and cultural activities (education, habit training, and playing); and (4) speech therapy. By means of these methods many palsied children have been greatly improved. Dr. Takagi stated that brain surgery itself is only a small part of the over-all process of rehabilitation and that its effect cannot be accurately evaluated until it has been followed by well prescribed exercises in self-rehabilitation.

[1] Tokyo, Japan.

**Results of Débridement of Tuberculous Foci and Its Indication.** Dr. E. Kondo [2] and Dr. K. Yamada [3] discussed the results obtained in 830 patients with bone and joint tuberculosis, treated at Kyoto University Medical School and observed for one to twenty-one years. When classified according to method of treatment, the results were: 29 per cent excellent and 14 per cent good in the group treated conservatively without streptomycin; 20 per cent excellent and 39 per cent good in the group treated conservatively with streptomycin; 44 per cent excellent and 16 per cent good in the group treated by Albee's operation without streptomycin; 35 per cent excellent and 29 per cent good in the group treated by Albee's operation with streptomycin; and 52 per cent excellent and 43 per cent good in the group treated by débridement, the best results in this group being obtained when streptomycin was used. Débridement in combination with streptomycin thus appeared to be the treatment of choice. Since 1951, the authors had advocated its use during the late tranquil stage of the disease, and this previously established principle was still accepted. Recently the increasing tendency to abuse the chemotherapeutic agents has caused the development of resistant strains, but in their series the authors had never experienced any resistance over ten gamma in the fifty-nine patients treated with total doses of up to sixty grams of streptomycin. For this reason they believed that the development of streptomycin-resistant strains can be disregarded at present. The authors concluded that the effects of antituberculous chemotherapy alone upon bone and joint tuberculosis are still limited and that in appropriate cases better results can be obtained by débridement combined with streptomycin.

**Arthrodesis in Joint Tuberculosis.** Dr. S. Kono [4] recommended arthrodesis combined with chemotherapy as a means of obtaining healing of the focus and restoration of a useful working joint. This method had been used in 130 patients with joint tuberculosis, sixty-four in the hip, twenty-nine in the knee, and twenty-one in other joints. Concerning indications, the author said that the operation should be performed during the tranquil stage of the disease. The method of operation described by the author was intra-articular bone fusion, débridement with iliofemoral arthrodesis being especially recommended for hip-joint tuberculosis, Hibb's method for knee-joint tuberculosis, and Gocht-Jones' method for shoulder-joint tuberculosis. In most of the operations, streptomycin (total dose, twenty-one grams) had been given. Fistulae had formed after operation in twenty-one patients but had not persisted more than six months except in two patients. The average length of immobilization after operation had been eight months for the hip lesions, seven for the shoulder lesions, and six for the knee and ankle lesions. In this series the first roentgenographic evidence of bone union had been found four or five months after operation. Final evaluation of the results as regards ankylosis of the treated joint revealed that success had been obtained in 100 per cent of the knee and wrist lesions, in 94 per cent of the shoulder and ankle lesions, and in 89 per cent of the hip lesions. Remarkable improvement in the patient's general condition and resumption of professional activity were found in every case one or two years after operation.

**Research on Functional Recovery of Tuberculous Joints.** Dr. R. Katayama [5] reported that in his clinical practice 42.9 per cent of the patients treated conservatively during the initial stage and 16.7 per cent of the patients treated during the acute stage had obtained some degree of functional recovery but that no patients treated during the chronic stage had obtained such recovery. Although it is well known that fixation of a joint combined with chemotherapy produces excellent results, some innovations in treatment will be necessary if the surgeon intends to take later measures to improve the function of the afflicted joint.

In this connection the author had tried such procedures as extirpation of morbid foci, joint resection with insertion of an intermediate membrane, and appliance of an acrylic head prosthesis to the resected joint. The number of patients treated by such surgical means had been 207. On the basis of this series, the author had concluded that functional as well as organic recovery may be obtained by the use of an acrylic prosthesis, and he reported that the patients to whom this method had been applied could support themselves by means of the afflicted limb an average of 4.4 months after operation. Furthermore, in 99.2 per cent the shortness of the limb resulting from joint resection had been corrected. Nevertheless, he felt that there are still many problems to be studied, including the following: (1) in patients with fistulae, use of an acrylic head prosthesis causes static infection; (2) in the shoulder joint, this prosthesis causes a decrease in function; (3) when inadequate chemotherapy has been given, the development of morbid foci tends to be aggravated by the use of a prosthesis; and (4) if the prosthesis is applied to a joint which has been insufficiently resected, there is great danger of relapse. In conclusion the author stated that permanent mobility and a complete cure may be obtained in some cases when appropriate treatment is used in combination with chemotherapy.

[2] Kyoto, Japan.
[3] Tokushima, Japan
[4] Niigata, Japan.
[5] Tokyo, Japan.

**Conservative Treatment of Bone and Joint Tuberculosis.** Dr. K. Mikanagi [6], Dr. S. Hashimoto [7], Dr. S. Toriyama [8], Dr. K. Sakaki [9], Dr. M. Matsunaga [10], Dr. T. Sekiguchi [11], and Dr. Y. Igari [12] discussed the results of conservative treatment of bone and joint tuberculosis. Two hundred and fifty patients had been treated during a period of more than one year. Spinal caries had been easily remedied by this treatment, especially in children, and twenty-five of thirty-two patients with spinal caries had shown great improvement. It had been found that some joint mobility could be obtained if the diagnosis was established during the early stage, although the authors' experiences in this connection were insufficient. In patients with multiple foci, chemotherapy had not been found so effective, and in eight of thirteen patients a complete cure had not been obtained.

**Rehabilitation of Patients with Bone and Joint Tuberculosis.** Dr. E. Marumo [13], Dr. M. Utsubo [14], and Dr. N. Ando [15] had initiated rehabilitation measures during the recovery stage in 215 cases of bone and joint tuberculosis. As a result of their treatment 87.5 per cent of the patients had returned to their original occupations or had been able to resume normal every-day living.

**Studies on the Leading Principles of Surgical Procedures of Bone and Joint Tuberculosis.** Dr. T. Igari [16] discussed the leading principles of surgical treatment of bone and joint tuberculosis. The author and associates had treated 326 patients with this disease. Of 100 patients treated by chemotherapy, forty-three had also been subjected to surgery; the results of this treatment had been successful in twelve patients, satisfactory in sixteen, and unsatisfactory in fifteen. The author felt that extirpation of the foci can often be carried out when it is not possible to perform posterior spine fixation and that this method should be further subjected to strict scrutiny. He stated that when the foci are positively attacked, bone transplantation to the areas of the foci should be done in order to provide biological stimulation.

**Late Results of Operative Treatment for Bone and Joint Tuberculosis.** Dr. N. Shiotsu [17] and Dr. T. Otsuka [18] had studied statistically the late results obtained by spondylodesis in sixty-four patients with spinal caries and the late results obtained by focal débridement in ninety-eight patients with 108 lesions in the extremities. Although focal débridement combined with streptomycin had proved to be the best operation, it had been found that when the former could not be performed, the fusion operation was also effective.

**Late Results of Spondylodesis and Spinal-Body Curettage for Spinal Caries.** Dr. T. Wakatsuki [19], Dr. Z. Funazaki [20], and Dr. S. Sakai [21] had performed spondylodesis in fifty-four patients and spinal-body curettage in eighty-five patients. Forty-three of the former and forty-five of the latter had been alive two years after the operation. The authors had concluded that spinal-body curettage is superior to spondylodesis. They had also concluded that the results in patients treated by operation are always better than those in patients not treated by operation and that end results in general are closely correlated with such other factors as family income and the presence of abscesses.

**Characteristics and Clinical Significance of Tuberculous Bacillus in Bone and Joint Tuberculosis.** Dr. A. Takayama [22], Dr. T. Otani [23], Dr. J. Sato [24], Dr. K. Yamasaki [25], and Dr. H. Tsugane [26] had carried out histopathological and bacteriological experiments in which animals had been inoculated in the knee with material taken from lesions in forty-seven human patients treated by chemotherapy for four months to two years. The findings of these experiments were as follows: (1) tuberculous bacilli with the ability to produce the disease still existed when the microscopic findings were positive and the results of culture were negative; (2) tuberculous bacilli could be found histologically, by guinea-pig inoculation and tissue section, even during the recovery stage following extended chemotherapy; and (3) when the investigation was made by the microscopic method, variation in color was seen.

**Inhibitory Activity of Cold-Abscess Pus on the Growth of Tuberculous Bacilli.** Dr. S. Tsutsumi [27] had analyzed various factors in the inhibitory activity of cold-abscess pus and reported that this activity was not influenced by heating at 60 degrees centigrade for thirty minutes but was decreased by heating at 100 degrees centigrade for thirty minutes. He also reported that the antimycobacterial substance which produces the inhibitory activity can permeate a collodion membrane. He suggested that this substance might consist of compounds of low molecular weight rather than of substances of high molecular weight such as proteins, enzymes, or immune bodies.

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[26] Tokyo, Japan.
[27] Kyoto, Japan.

**Experiences with Blocking of the Function of the Globus Pallidus for Athetosis.** Dr. K. Masabayashi [28], Dr. Manabe [29], Dr. H. Narabayashi [30], Dr. T. Okuma [31], and Dr. S. Shikiba [32] had attempted, during the previous four years, to block the function of the globus pallidus by means of injections of procaine suspended in oil and wax. Fifteen patients between the ages of seventeen and twenty-nine years had been treated in this manner; in most of these patients athetosis had disappeared immediately, and voluntary and delicate movements of the hands had become possible within several weeks. Some reappearance of symptoms had been observed, but this had been slight and the effects of the operation had seemed to be sustained for about four years.

**Full-Thickness Skin Grafts.** Dr. T. Morotomi [33], Dr. T. Saito [34], Dr. T. Nakamura [35], Dr. K. Tin [36], and Dr. I. Hukui [37] reported that clinical and laboratory experiments had demonstrated that full-thickness skin grafts in which multiple small incisions have been made are superior to other types of skin grafts.

**Bone Induction and Bank-Bone Transplantation.** Dr. I. Maeyama [38], Dr. T. Matsumoto [39], and Dr. J. Koga [40], accepting the theory that the transplantation of bladder mucosa into a muscle results in induction of heterotropic ossification, had believed that the transplantation of preserved deep-frozen bone would produce the same result and had, therefore, performed this procedure in forty patients. On the basis of this series they had concluded that bank-bone grafts are as useful in this regard as are fresh grafts. They had found some delay in healing but felt that this might not have been caused by the bank bone but rather had been due to other factors.

**Lower-Extremity Equalization by the Use of Staples and Screws.** Dr. Y. Toyoshima [41], Dr. H. Okuno [42], Dr. A. Kajiwara [43], Dr. T. Kondo [44], Dr. S. Oishi [45], Dr. T. Fujishita [46], Dr. S. Matuo [47], and Dr. K. Maeda [48] reported sixty-three cases (thirty-one cases of poliomyelitis and nineteen of hip-joint tuberculosis) in which stapling had been done. Of 481 staples used, nine had been broken, twenty-three had become loose, and 141 had been flattened by epiphyseal growth. Staples had been found flattened as early as three months after operation, whereas they had been found broken only after seventeen months. In twelve patients screws had been placed adjacent to the epiphyseal line and staples had been placed on the opposite side. The greatest gain in lower-extremity equalization had been 3.2 centimeters. The authors preferred the atraumatic procedure to the more extensive stripping of the periosteum and emphasized that strict x-ray control must be maintained in order to determine precisely the location of the epiphyseal line.

**Clinicopathological Studies of Bone Tumors.** Dr. I. Kojima [49] had made a clinicopathological study of 176 bone tumors during the previous ten years. Seven lesions had been found to be the result of other diseases and four had been excluded because of inadequate clinicopathological data. The remaining 165 tumors had been classified according to Lichtenstein's system. It was found that in this series no benign tumors had resulted in death and that the prognosis for fibrosarcoma (especially the periosteal type) was relatively favorable. In conclusion the author advocated that treatment should be selected on the basis of the histological evidence of malignant growth and should be as radical as possible if the malignant growth is found to be over Grade II.

**Giant-Cell Tumor of Bone.** Dr. S. Toriyama [50], Dr. I. Tange [51], Dr. S. Mizuno [52], and Dr. M. Urabe [53] had investigated the relationship of the clinical features of this tumor to its prognosis. In twenty-five patients, they had found that the best functional results were obtained by resection or curettage combined with the insertion of bone chips to fill the cavity. They stated that in the determination of the malignant growth of the tumor, such symptoms as expansion of the bone cortex (as seen in the roentgenogram), atypical cellular structure, and pulsation of the tumor are important.

**Closed Reduction for Congenital Dislocation of the Hip Joint.** Dr. S. Morita [54], Dr. Y. Akaboshi [55], and Dr. S. Kondo [56] had re-examined 317 patients with 468 congenital dislocations of the hip. These examinations had been made two to seventeen years after the primary treatment by closed reduction. On the basis of their findings of anatomical abnormalities, they had concluded that operative treatment, such as acetabuloplasty and derotation osteotomy, should be undertaken more often than it has been in the past. As the criteria for the selection of the operative treatment, they stated that the shape of the acetabulum, the CE angle as described by Wiberg, changes in the femoral head, and anteversion of the femoral neck should be

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taken into consideration. If either anteversion of the femoral neck or a deformity of the acetabulum is found, operative treatment should be carried out (two years after closed reduction for the former and three years after closed reduction for the latter).

**Treatment of Congenital Dislocation of the Hip Joint.** Dr. Y. Kobayashi [57], Dr. A. Shimizu [58], Dr. K. Kabata [59], and Dr. M. Kikuchi [60] had made a follow-up study of 700 hips treated between 1951 and 1953. They had found that the patients treated under anaesthesia had shown better results as regards the form of the upper femoral epiphysis but not as regards the construction of the acetabulum. Colonna's operation or a plastic operation in which an acrylic head had been used had resulted in good function of the joint in older children and in adults but not in younger children. Osteotomy had improved the function of the affected hip in children but had not been satisfactory in adults.

**Subtrochanteric Osteotomy for Congenital Dislocation of the Hip Joint.** Dr. K. Shima [61], Dr. H. Suzuki [62], and Dr. Y. Nakabayashi [63] had reviewed forty-one cases of irreducible congenital dislocation of the hip treated by subtrochanteric osteotomy. The results had been as follows: pain had disappeared in 62.5 per cent of thirty-two hips, fatigue had disappeared in 44.4 per cent of forty-five hips, and Trendelenburg's sign had disappeared in 62.8 per cent of forty-three hips. With regard to gait, five of thirty patients had shown excellent results and five others had shown good results.

**Follow-up Study on the Shelf Operation for Congenital Dislocation of the Hip.** Dr. N. Takagishi [64], Dr. S. Miwa [65], Dr. K. Iwakiri [66], and Dr. T. Nomura [67] had made a follow-up study of 135 patients with 175 congenitally dislocated hips. In this series, forty-two hips had been treated by the shelf operation, twenty-nine had been treated by closed reduction, and thirty-three hips had not been treated. In the forty-one patients treated by the shelf operation in combination with open reduction, closed reduction, or Judet's operation the results were satisfactory: fourteen had good results and eighteen were improved. The authors concluded that the shelf operation should be performed if there is no evidence of ossification of the acetabular roof and that Lance's method gives much better results than Spitzy's method.

**Clinicopathological Study on Loose Bodies.** Dr. Y. Sasagawa [68] had made a clinicopathological study of seventy-two cases of loose bodies (osteochondritis dissecans and osteochondromatosis). Concerning the mechanism of development, he had concluded that certain individuals are particularly susceptible to osteochondromatosis and that in these individuals the disease is stimulated by trauma or inflammation and develops through a process of metaplasia.

**New Devices for the Correction of Knee-Joint Flexion Contracture.** Dr. S. Mizumachi [69] and Dr. S. Hamada [70] presented new devices to overcome flexion contracture of the knee. The principles involved included: (1) maintenance of extension of the leg by means of a force exerted parallel to the long axis of the leg, and (2) exertion of pressure on the patella in order to facilitate the maintenance of extension.

**Arthroplasty of the Knee.** Dr. T. Amako [71] and Dr. T. Inoue [72] had performed arthroplasty on fifty knees during the previous five years. In these operations chromicized autogenous fascia lata had been used. The results obtained had been as follows: sixteen excellent, twenty-two good, eleven poor, and one unsatisfactory. The authors stated that the chief factor influencing the results of arthroplasty is not pathological change in the joint but rather injury to the femoral muscle at operation.

**Treatment of Femoral-Neck Fractures with the Godoy Moreira Stud Bolt.** Dr. K. Watanabe [73], Dr. T. Sageshima [74], Dr. M. Matsubara [75], Dr. M. Ota [76], and Dr. S. Wataya [77] reported the use of the Godoy Moreira stud bolt in ten patients with old and fresh fractures of the femoral neck. The authors felt that this bolt provides better fixation than does the Smith-Petersen nail and that by its use bone union can be obtained sooner and rotation of the femoral head can be avoided. They advocated that at the time of insertion of this bolt the joint capsule should be incised in order to obtain better reduction of the fractured bone.

**Prosthetic Operation for Femoral-Neck Fractures.** Dr. M. Tsuchida [78] and Dr. Y. Nakai [79] had treated seventeen patients with femoral-neck fractures by the insertion of a prosthesis. They stated that this operation is an excellent treatment if it is used when the following conditions are present: (1) old non-union, (2) necrosis of the femoral head, (3) severe dislocation of the femoral head, and (4) strong shearing forces.

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**ROBERT MARSHALL WANSBROUGH**

**1900–1956**

On May 24, 1956, Dr. Robert Marshall Wansbrough died of a heart attack. He was apparently in good health that morning. He had just completed an operation at the Children's Hospital and was driving to another hospital to see a patient on whom he had operated the night before, when the attack occurred. Death came to him at the height of his surgical career.

Dr. Wansbrough — Tim, as he was called — was born in Grand Valley, Ontario, on January 14, 1900. He was graduated in medicine from the University of Toronto in 1924, and spent his postgraduate years at the Hospital for Sick Children, the Toronto General Hospital, and the Crile Clinic in Cleveland. As was the custom in those days, his surgical training was broad rather than limited to any one specialty. He was appointed to the surgical staff of the Hospital for Sick Children in 1929, and during his twenty-seven years on this staff, he looked after surgical patients of almost every type (probably more genito-urinary and abdominal cases than orthopaedic cases). He was appointed Surgeon-in-Chief in November 1950, just before the Hospital moved to its new building. At the same time he was appointed Associate Professor of Surgery at the University of Toronto, and he held both these posts until the time of his death.

At the beginning of World War II, he joined the Royal Canadian Army Medical Corps and in January 1940, he went overseas with No. 15 General Hospital, the first Canadian hospital to go overseas. He was later appointed Chief Surgeon of this hospital with the rank of Lieutenant Colonel.

He did not do much writing and what few papers he published were nearly all on genito-urinary and abdominal subjects. He was a member of The American Orthopaedic Association, The Canadian Orthopaedic Association, the Central Surgical Association, and the Canadian Society of Clinical Surgeons.

As a surgeon, he was known for his sound judgment and reliability. His main object seemed to be that all the patients should be well looked after, not only given the best surgical care, but also treated with the utmost kindness. He took more interest in the postoperative course and comfort of his patients, whether they were in public or private wards, than most surgeons do. He liked to see all his old patients and always remembered their names and all about them. His capacity for work was tremendous. Toward the end of the war and just after the war, when the Hospital was badly understaffed, he had to look after most of the surgical patients. This excessive load of work may have had something to do with his untimely end. He will be greatly missed by a large number of patients and by the great many physicians and surgeons who were his friends.

## PRESCOTT I E BRETON

### 1872–1956

Dr. Le Breton was born in Paterson, New Jersey, on November 4, 1872. He received part of his early training at Racine College in Wisconsin. He had selected this college because he fancied one of the teachers, whom he had met in the East, and he went there alone at the age of twelve.

While there he enjoyed his first major musical experience—in a Gilbert and Sullivan operetta, "Trial by Jury". He recalled later, "I was the entire orchestra". To pay for his Columbia University education (A.B. and M.D., 1896), he played the organ in a Paterson, New Jersey, church. He continued to play the organ almost to the day of his death, and in later years it became a tradition for him to play the music for the ceremonies of the nurses' graduation at the Mound Park Hospital in St. Petersburg, Florida. As important in his life as his love for music was his love for sports. He played baseball in college and was a sharpshooter in New York's famous 7th Regiment. Even as recently as 1950, he was to be seen daily bowling on the green in St. Petersburg's Mirrow Lake Park.

Dr. Le Breton's early intern days were spent in the Roosevelt Hospital in New York, which, at the turn of the century, was located in the "tenderloin", "with its bumpy cobblestones, noisy wagons, leisurely clopping horses, dirt, shrill children's voices, quick knives and dim gas street lights".

In 1905, after completing his internship, he established his practice in Buffalo, New York. At first he worked in the several fields of anaesthesiology, neurology, and orthopaedic surgery; but later he decided on orthopaedic surgery. In this field, the crippled child became his absorbing interest.

He was elected a member of The American Orthopaedic Association in 1911. Of his work in Buffalo, Dr. Frank Potts of Buffalo has written: "During the time Prescott was in Buffalo, he was connected with the Buffalo General Hospital and The Children's Hospital, as attending orthopaedic surgeon; and he practically developed the Crippled Children's Guild alone; he was the first to put his heart and soul into this institution, and he built it into one of the earliest and most outstanding clinics for the care of crippled children. Great credit must be given him for this accomplishment. . . . Prescott took a great personal interest in his patients, and he had the happy faculty of making them aware of it."

In 1928, for personal and family reasons, Dr. Le Breton left Buffalo to go to Florida, where he finally established a practice in St. Petersburg. No sooner had he adopted Florida as his home, than he started holding rural clinics for crippled children in the areas in which the need was great. This mission reached its fruition in the establishment of the American Legion Hospital for Crippled Children in St. Petersburg.

During the War, when he was in his seventies, he was harassed by the great responsibility of serving as the only orthopaedic surgeon in the community. In 1946, he retired permanently from active work. Behind him lay a career of uninterrupted and faithful devotion to crippled children, a record of meticulous surgery, and an enviable pattern of honesty in its performance. He was an innately modest man, who lived a full life and gave unstinting service to mankind.

# News Notes

The Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held in Chicago, Illinois, January 26 to 31, 1957. The provisional program of the meeting follows:

Saturday, January 26

Joint Meeting with The Orthopaedic Research Society

2:00 P.M.

The Three Dimensional Anatomy of Haversian Systems.
William H. Harris, M.D., Boston, Massachusetts.
Jonathan Cohen, M.D., Boston, Massachusetts.
Discussion by Ernest Gardner, M.D., Detroit, Michigan.
Albert B. Ferguson, Jr., M.D., Pittsburgh, Pennsylvania.

Compression Studies on Bone in Tissue Culture.
George G. Rose, M.D., Houston, Texas.
Thomas O. Shindler, M.D., Houston, Texas.
Discussion by Robert D. Ray, M.D., Chicago, Illinois.
G. W. N. Eggers, M.D., Galveston, Texas.

The Histochemistry of Aging Periosteum.
Edgar A. Tonna, Ph.D., New York, N. Y.
Discussion by Isidor Gersh, M.D., Chicago, Illinois.
Roscoe Mossman, M.D., Seattle, Washington.

The Effect of Total Body Irradiation on Bone Transplants in Parabiotik Animals.
W. F. Enneking, M.D., Chicago, Illinois.
Avrum Gratch, M.D., Chicago, Illinois.
Discussion by Charles H. Herndon, M.D., Cleveland, Ohio.
Andrew W. Bassett, M.D., New York, N. Y.

Repair of Bone Transplant Fractures.
Michael Bonfiglio, M.D., Iowa City, Iowa.
Discussion by Crawford Campbell, M.D., Albany, New York.
George Hyatt, M.D., Bethesda, Maryland.

Epiphyseal Cartilage as an Endocrine Organ.
Edwin G. Bovill, Jr., M.D., San Francisco, California.
Discussion by Thomas Brower, M.D., Pittsburgh, Pennsylvania.
Herbert Pedersen, M.D., Detroit, Michigan.

Sunday, January 27

Scientific Sessions: The American Academy of Orthopaedic Surgeons

2:00 P.M.

The Double Pin Method in the Treatment of Fractures of the Tibia and Fibula.
Milton J. Wilson, M.D., New York, N. Y.
Jack Henry Mower, M.D., New York, N. Y.
Herbert G. Cohen, M.D., New York, N. Y.
Discussion by Roger Anderson, M.D., Seattle, Washington.
Colonel Milton S. Thompson, Washington, D. C.

Metastatic Carcinoma of Big Toe.
Gerald S. Ahern, M.D., Corpus Christi, Texas.
John Pilcher, M.D., Corpus Christi, Texas.
Discussion by Murray Copeland, M.D., Washington, D. C.
Frederick G. Gaenslen, M.D., Milwaukee, Wisconsin.

An Operation for Congenital Club-Hand.
Ralph T. Lidge, M.D., Chicago, Illinois.
Discussion by Robert E. Carroll, M.D., New York, N. Y.
Sterling Bunnell, M.D., San Francisco, California.

Monday, January 28

11:00 A.M.

Criteria for Determining the Proper Level of Amputation in Occlusive Vascular Disease.
Joseph M. Janes, M.D., Rochester, Minnesota.
Patrick J. Kelly, M.D., Rochester, Minnesota.
Discussion by Robert Mazet, Jr., M.D., Los Angeles, California.
Ormond Julian, M.D., Chicago, Illinois.

Presidential Address.
William T. Green, M.D., Boston, Massachusetts.
2:00 P.M.
Evaluation of an Operative Series of Lumbar-Disc Herniations.
F. S. Webster, M.D., Lincoln, Nebraska.
Donald Smiley, M.D., Lincoln, Nebraska.
Discussion by H. Herman Young, M.D., Rochester, Minnesota.
Joseph B. Davis, M.D., Portland, Oregon.
Posterolateral Bone Grafting for Fusion of the Lumbar and Lumbosacral Spine.
Melvin B. Watkins, M.D., New York, N. Y.
Discussion by Marcus Stewart, M.D., Memphis, Tennessee.
Walter A. L. Thompson, M.D., New York, N. Y.
Treatment of Certain Spine Disorders by Anterior Disc Removal and Interbody Fusion.
George W. Smith, M.D., Augusta, Georgia.
Robert A. Robinson, M.D., Baltimore, Maryland.
Discussion by J. E. M. Thomson, M.D., Lincoln, Nebraska.
James Gordon Petrie, M.D., Montreal, Canada.
Spine Osteotomy for Correction of Severe Flexion Deformity.
Paul E. McMaster, M.D., Beverly Hills, California.
Discussion by William A. Larmon, M.D., Chicago, Illinois.
Carroll B. Larson, M.D., Iowa City, Iowa.
Prevention and Treatment of Paraplegic Pressure Sores.
J. T. O'Hanlan, M.D., Fisherville, Virginia.
Discussion by O. Anderson Engh, M.D., Washington, D. C.
Clinton Compere, M.D., Chicago, Illinois.
Experience Using Gastrocnemius Recession: Five-Year Report of Cases.
Luther M. Strayer, Jr., M.D., Bridgeport, Connecticut.
Discussion by George W. N. Eggers, M.D., Galveston, Texas.
Frederic C. Bost, M.D., San Francisco, California.
Affect of Tendo-Achillis Lengthening on Power of Gastrocnemius and Soleus Muscles.
Lewis Cozen, M.D., Los Angeles, California.
Mrs. L. Martin, P.T., Los Angeles, California.
Discussion by Verne Inman, M.D., San Francisco, California.
David S. Grice, M.D., Boston, Massachusetts.
Observation of Neuropathic (Charcot) Joints Occurring in Diabetes Mellitus.
Julian E. Jacobs, M.D., Charlotte, North Carolina.
Discussion by James P. Miller, M.D., Baltimore, Maryland.
Robert Cram, M.D., Philadelphia, Pennsylvania.

Tuesday, January 29

11:00 A.M.
Kappa Delta Award for Research.
Compression Technique in Ununited and Infected Fractures.
Thomas King, M.D., Australia.
Television Program on Cerebral Palsy.
Moderator: Harry E. Bennett, M.D., Chicago, Illinois.
Panel: Winthrop Phelps, M.D., Baltimore, Maryland.
Lenox Baker, M.D., Durham, North Carolina.
H. Relton McCarroll, M.D., St. Louis, Missouri.
2:00 P.M.
Experience with the Use of the Milwaukee Brace for Paralytic Scoliosis.
James B. Wray, M.D., Winston-Salem, North Carolina.
Charles E. Irwin, M.D., Atlanta, Georgia.
The Milwaukee Brace in the Treatment of Scoliosis.
Walter P. Blount, M.D., Milwaukee, Wisconsin.
Albert C. Schmidt, M.D., Milwaukee, Wisconsin.
Follow-up on Scoliosis.
Joseph C. Risser, M.D., Pasadena, California.
Discussion by Charles H. Frantz, M.D., Grand Rapids, Michigan.
William H. von Lackum, M.D., New York, N. Y.
Frederick P. Dewar, M.D., Toronto, Canada.
Repair of the Articular Surface of the Femoral Head Following Arthroplasty.
Marshall R. Urist, M.D., Los Angeles, California.

Discussion by Philip Wilson, M.D., New York, N. Y.
James Bateman, M.D., Toronto, Canada.

Osteotomy-Bunionectomy for Severe Hallux Valgus.
C. Leslie Mitchell, M.D., Detroit, Michigan.
Discussion by George Hammond, M.D., Boston, Massachusetts.
Earle D. McBride, M.D., Oklahoma City, Oklahoma.

Familial Osteochondritis Dissecans with Associated Tibia Vara.
William Tobin, M.D., Washington, D. C.
Discussion by Brandon Carrell, M.D., Dallas, Texas.
Donald E. King, M.D., San Francisco, California.

Fixation of Intracapsular Fractures of the Femur with Multiple Nails: End Result Study.
M. T. Modny, M.D., Glen Ridge, New Jersey.
H. G. Kunz, M.D., Montclair, New Jersey.
Discussion by Austin T. Moore, M.D., Columbia, South Carolina.
George J. Garceau, M.D., Indianapolis, Indiana.

Traumatic Periostitis in Children.
Morris S. Friedman, M.D., South Bend, Indiana.
Discussion by J. Vernon Luck, M.D., Los Angeles, California.
William H. Bickel, M.D., Rochester, Minnesota.

Detailed X-ray Study of the Lumbosacral Spine in Normal Children.
C. A. Splitholf, M.D., Oakland, California.
Discussion by John K. Wickstrom, M.D., New Orleans, Louisiana.
Alan DeForest Smith, M.D., New York, N. Y.

Wednesday, January 30

11:00 A.M.

The Use of a Replacement Prosthesis for the Treatment of Fresh Femoral Neck Fractures. (Committee Report to The American Academy of Orthopaedic Surgeons)
Fred C. Reynolds, M.D., St. Louis, Missouri.
Discussion by Joseph S. Barr, M.D., Boston, Massachusetts.
Carl E. Badgley, M.D., Ann Arbor, Michigan.

Twenty-Five Year Follow-up of Leg-Lengthening Procedures.
Harold A. Sofield, M.D., Oak Park, Illinois.
Edward A. Millar, M.D., Wilmette, Illinois.
Discussion by George O. Eaton, M.D., Baltimore, Maryland.
C. H. Crego, Jr., M.D., St. Louis, Missouri.

Shortening of the Metatarsal Shaft for Correction of Plantar Keratoses.
Nicholas J. Giannestras, M.D., Cincinnati, Ohio.
Discussion by Rex L. Diveley, M.D., Kansas City, Missouri.
Philip Lewin, M.D., Chicago, Illinois.

2:00 P.M.

Coxa Plana in Congenital Dislocation of the Hip.
Gary DeN. Hough, III, M.D., Springfield, Massachusetts.
Discussion by Jesse T. Nicholson, M.D., Philadelphia, Pennsylvania.
Edward L. Compere, M.D., Chicago, Illinois.

Legg-Calvé-Perthes Disease.
Harry R. Gossling, M.D., Hartford, Connecticut.
Russell O. Gee, M.D., Newington, Connecticut.
Maurice M. Pike, M.D., Hartford, Connecticut.
Discussion by M. Beckett Howorth, M.D., Stamford, Connecticut.
Charles W. Goff, M.D., Hartford, Connecticut.

Iliopsoas Transplant. Femoral Osteotomy for Paralytic Dislocation.
Joseph L. Fleming, M.D., Detroit, Michigan.
Discussion by Floyd Jergesen, M.D., San Francisco, California.
Wilbur Weston, M.D., Los Angeles, California.

Functional Fixation of Intracapsular Fractures of the Femur.
William K. Massie, M.D., Lexington, Kentucky.
Discussion by Robert T. McElvenney, M.D., Chicago, Illinois.
Harrison L. McLaughlin, M.D., New York, N. Y.

The Küntscher Method of Intramedullary Fixation.
Professor Gerhard Küntscher, Germany.

Skeletal Changes in a Series of Sickle-Cell Cases.
Richard W. Leong, M.D., Houston, Texas.
Multiple Myeloma.
Bradley L. Coley, M.D., New York, N. Y.
Norman L. Higinbotham, M.D., New York, N. Y.
Kenneth C. Francis, M.D., New York, N. Y.
The Changing Bone Picture in Multiple Myeloma.
William S. Smith, M.D., Columbus, Ohio.
Thomas J. Klug, M.D., Columbus, Ohio.
Discussion by Mary Sherman, M.D., New Orleans, Louisiana.
Ralph K. Ghormley, M.D., Rochester, Minnesota.
Paul H. Curtiss, Jr., M.D., Cleveland, Ohio.

Thursday, January 31

9:00 A.M.
Débridement and Panarthrodesis for Spinal Tuberculosis and Simulative Disease. Preliminary Report.
Richard H. Hall, M.D., Long Beach, California.
B. M. Adamson, M.D. Long Beach, California.
Treatment of Tuberculous Bone Disease by Surgical Drainage Combined with Antibiotics.
M. S. DeRoy, M.D., Pittsburgh, Pennsylvania.
Harry Fisher, M.D., Pittsburgh, Pennsylvania.
Roy Temeles, M.D., Pittsburgh, Pennsylvania.
Fusion of the Spine for Tuberculosis in Children: A Long Range Follow-up Study.
Mather Cleveland, M.D., New York, N. Y.
David M. Bosworth, M.D., New York, N. Y.
J. William Fielding, M.D., New York, N. Y.
Panayiotis Smyrnis, M.D., Athens, Greece.
Discussion by John Royal Moore, M.D., Philadelphia, Pennsylvania.
Philip H. Moore, M.D., Edgecumbe, Alaska.
George B. Higley, M.D., New York, N. Y.
Congenital Absence of the Fibula.
T. Campbell Thompson, M.D., New York, N. Y.
Discussion by John J. Fahey, M.D., Chicago, Illinois.
Halford Hallock, M.D., New York, N. Y.
Fracture of the Intercondyloid Eminence of the Tibia.
Marvin Meyers, M.D., Los Angeles, California.
Francis M. McKeever, M.D., Los Angeles, California.
Discussion by Carlo Scuderi, M.D., Chicago, Illinois.
O. Sherwin Staples, M.D., Hanover, New Hampshire.
Fractures and Fracture-Dislocations of the Head of the Humerus.
Robert A. Knight, M.D., Memphis, Tennessee.
Ian A. Mayne, M.D., Memphis, Tennessee.
Discussion by Charles S. Neer, M.D., New York, N. Y.
Edwin F. Cave, M.D., Boston, Massachusetts.
The Pathomechanics of Peroneal Spastic Flatfoot.
Thomas Outland, M.D., Harrisburg, Pennsylvania.
Ian Murphy, M.D., Pittsburgh, Pennsylvania.
Discussion by Thomas Beath, M.D., Richmond, Virginia.
Edmond J. McDonnell, M.D., Baltimore, Maryland.
Operative Treatment of Recurrent Dislocation of the Patella in the Adult.
Francis E. West, M.D., San Diego, California.
Ralph Soto-Hall, M.D., San Francisco, California.
Discussion by Emil D. W. Hauser, M.D., Chicago, Illinois.
Ernest M. Burgess, M.D., Seattle, Washington.

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The Twelfth Annual Meeting of the **American Society for Surgery of the Hand** will be held at the Palmer House, Chicago, Illinois, on Friday, January 25, 1957, under the Presidency of Dr. L. D. Howard, Jr.

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The Eighth Annual Meeting of the **Tennessee State Orthopaedic Society** was held on March 18, 1956, under the Presidency of Dr. John J. Killeffer, in Chattanooga, Tennessee.

During the morning scientific session the following papers were presented:

Medial Release Operation for Club-Foot. Dr. Sagar Datt Sikand, New York University-Bellevue Medical Center, New York City;

Fracture-Dislocation of Femoral Head. Dr. Paul C. Thompson, Chattanooga;

Interesting Case Presentation. Dr. Robert C. Robertson, Chattanooga;

Polyostotic Fibrous Dysplasia. Dr. Maurice Canon, Chattanooga;

Scapulo-costal Syndrome. Dr. Richard Donaldson, Chattanooga;

Soft-Tissue Calcification. Dr. John J. Killeffer, Chattanooga;

Unusual Case Report. Dr. W. Houston Price, Chattanooga.

In the afternoon Dr. Ignacio V. Ponseti, State University of Iowa, Iowa City, Iowa, spoke on Lesions of Mesodermal Tissue Caused by Aminonitriles. Considerable discussion followed this most stimulating presentation.

Following the scientific session, a business meeting was held, and the following officers were elected for the ensuing year:

*President:* Jarrell Penn, M.D., Knoxville;

*Vice-President:* Harrison O. Bourkard, Jr., M.D., Knoxville;

*Secretary:* C. Sanford Carlson, M.D., Knoxville.

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The Annual Meeting of the **Minnesota-Dakota-Manitoba Orthopedic Society** was held in Red Wing, Minnesota, on September 14 and 15, 1956, under the Presidency of Dr. Edward H. Juers. The following officers were elected:

*President:* John Feuling, M.D., Duluth, Minnesota;

*Secretary:* H. L. Ahrlin, M.D., Rapid City, South Dakota;

Dr. Wesley H. Burnham was re-appiinted Treasurer for the ensuing year.

The 1957 Meeting will be held in Duluth, Minnesota.

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The **Clinical Orthopaedic Society** held its Forty-fourth Annual Meeting in Cleveland, Ohio, October 5 and 6, 1956, at the Cleveland Medical Library under the Presidency of Dr. I. S. McReynolds of Houston, Texas. As is customary with the Clinical Orthopaedic Society, the orthopaedic surgeons of the local community gave the entire program. At the final executive session twenty new members were elected to Regular Membership. Officers elected were:

*President:* Dr. Neill Garber, Indianapolis, Indiana;

*Vice-President:* Dr. Garrett Pipkin, Kansas City, Missouri;

*Secretary-Treasurer:* Dr. Marcus Stewart, Memphis, Tennessee.

The Forty-Fifth Annual Meeting will be held in Kansas City, Missouri, on October 11 and 12, 1957.

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**The Charles LeRoy Lowman School for Handicapped Children** was dedicated in North Hollywood, California, on October 18, 1956. A regular school curriculum is pursued and, in addition, there is occupational therapy, physical therapy, speech therapy, and special training as required. Children are accepted from age three through the eighth grade. There are at present 222 children enrolled in the school. Virtually all handicapped children are accepted, but cerebral palsy and late poliomyelitis patients constitute the majority of students.

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The First **Congreso Argentino de Cirugia Ortopedica y Traumatologia** was held in Mar Del Plata, November 29, 30, and December 1, 1956. Dr. Isidro Castillo Odena was president of the Executive Committee. Papers were presented on:

Neck and Arm Pain. Dr. Leoncio Luis Fernández.

Traumatic Lesions of the Ligaments of the Knee. Dr. Pedro Gamberoni.

Osteoporosis. Dr. Nora Bloise de Napolitano and Dr. Isidro Blumenfeld.

Roundtable Discussion of Free Flexor Tendon Grafting in the Hand. Dr. Felipe Oleaga Alarcón, Moderator.

Present Treatment of Giant-Cell Tumors. Dr. José Valls.

Indications for and Results of Subtrochanteric Osteotomy. Dr. Carlos E. Ottolenghi.

Present Treatment of Pott's Disease. Dr. Guillermo Allende.

Hip Arthrodesis. Dr. Oscar Maottoli.

Child Life
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1 Bulb-shaped heel fits perfectly, snugly, without biting or irritation.
2 Ample displacement for the "cuboid roll."
3 Ample height at the large toe joint area for freedom in flexing.
4 Generous height at the small toe area to prevent irritation to the fifth toe.
5 Ample width and height over the toes give room enough for maximum growth.

## Arch Feature Last

1 Slight contouring for the forefoot.
2 Medial wedge removed from last for added support.
3 Heel two widths narrower for snug fit.
4 Ample width and height over the toes give room enough for maximum growth.
5 Generous height at the small toe area to prevent irritation to the fifth toe.
6 Ample displacement for the "cuboid roll."

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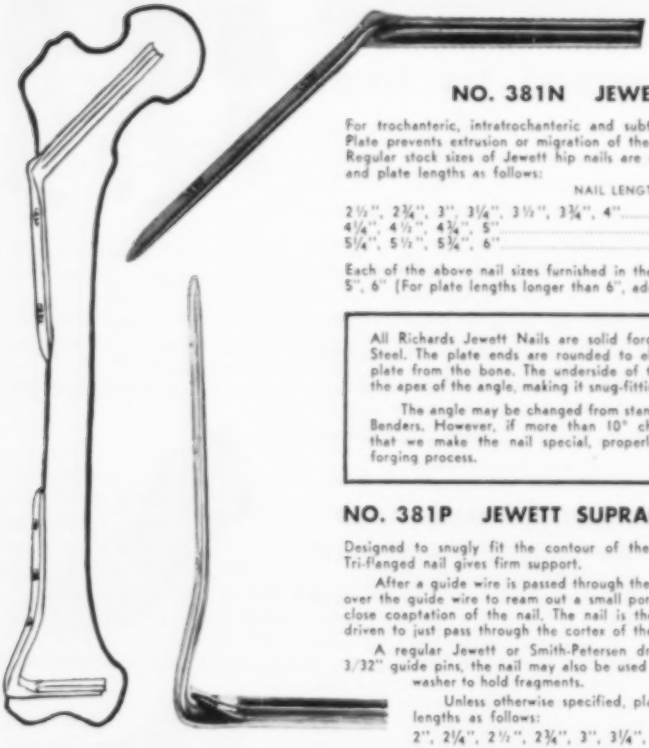

## NO. 381N JEWETT HIP NAIL

For trochanteric, intratrochanteric and subtrochanteric fractures of the femur. Plate prevents extrusion or migration of the Smith-Petersen nail portion.
Regular stock sizes of Jewett hip nails are cannulated, angle of 135°, with nail and plate lengths as follows:

NAIL LENGTHS

2½", 2¾", 3", 3¼", 3½", 3¾", 4" ..... **$12.50** each
4¼", 4½", 4¾", 5" ..... **13.50** each
5¼", 5½", 5¾", 6" ..... **14.50** each

Each of the above nail sizes furnished in the following plate lengths: 2", 3", 4", 5", 6" (For plate lengths longer than 6", add $1.25 per inch).

All Richards Jewett Nails are solid forged of one piece SMO Stainless Steel. The plate ends are rounded to eliminate abrupt protrusion of the plate from the bone. The underside of the plate is curved completely to the apex of the angle, making it snug-fitting to the bone.

The angle may be changed from standard by using the No. 414 Jewett Benders. However, if more than 10° change is desired, we recommend that we make the nail special, properly forming the angle in our hot forging process.

## NO. 381P JEWETT SUPRACONDYLAR NAIL

Designed to snugly fit the contour of the condyles and shaft of the femur. Tri-flanged nail gives firm support.

After a guide wire is passed through the condyles, a ½" D. reamer is placed over the guide wire to ream out a small portion of the lateral cortex to provide close coaptation of the nail. The nail is then placed over the guide wire and driven to just pass through the cortex of the medial condyle.

A regular Jewett or Smith-Petersen driver may be used. Cannulated for 3/32" guide pins, the nail may also be used in conjunction with a tibia bolt and washer to hold fragments.

Unless otherwise specified, plate length of 6" furnished, with nail lengths as follows:

2", 2¼", 2½", 2¾", 3", 3¼", 3½", 3¾", 4" ..... **$17.50**

## NO. 381S JEWETT SHOULDER NAIL

Indicated for fractures of the upper end of the humerus, mainly in the surgical neck area, or in fractures involving both the anatomical and the surgical neck in some instances.

Also adaptable for rotation osteotomies in the upper end of the femur in the young patient. The nail is not long enough to go into the epiphysis of the head of the femur yet is long enough to give stability with the use of a plaster spica. Nail is removed following complete healing of the bone.

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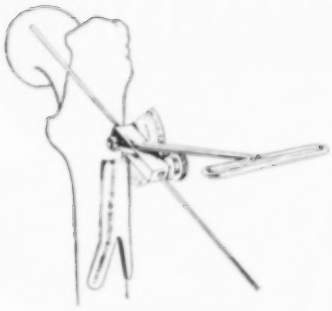
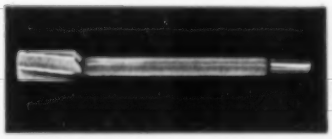


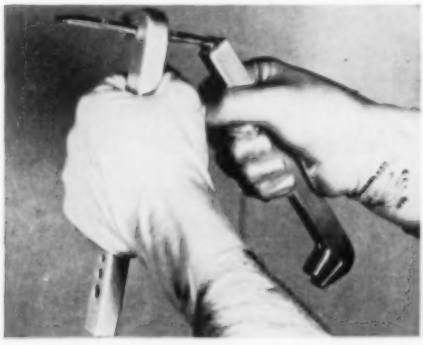
**NO. 381GA ADJUSTABLE JEWETT NAIL GUIDE.....$25.00**

Stainless Steel. Adjustable with quick positive lock. Protractor reading instantly gives correct angle. Guide pin may be inserted and then its angle measured, or Guide may be used to give pre-determined angle to pin.



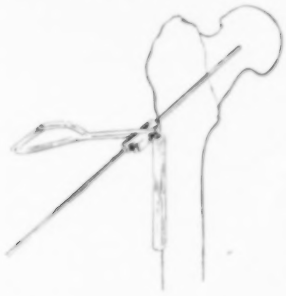
**NO. 381R REAMER.....$12.00**

Cannulated, 1/2" diameter, stainless steel



**NO. 414 PAIR JEWETT BENDERS.....$12.00**

Lightweight yet strong, made of heat treated aluminum alloy. Will not mar or nick SMO stainless bone plates. The nail end of the Jewett Nail is inserted into one end of the benders and the plate is gripped by the sturdy jaw of the other for bending. Also useful in bending and forming bone plates, intramedullary nails, and for twisting heavy plates.

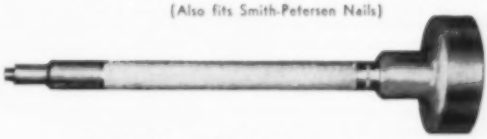


**NO. 381G JEWETT NAIL GUIDE.....$10.00**

Non-adjustable. For use as a drill jig only, giving an exact angle of 135° to the guide wire. Stainless.

**NO. 381D DRIVER,** stainless .....$ 7.00

(Also fits Smith-Petersen Nails)



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**NO.106A GUIDE PIN,** stainless

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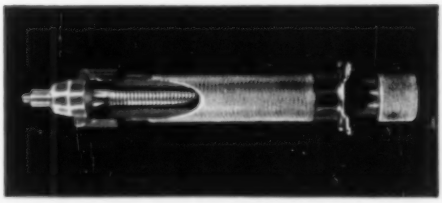

**NO. 381E JEWETT NAIL EXTRACTOR,** stainless.....$25.00

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In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

Mr. Louis C. Weld, President of G. W. Chesbrough Co., demonstrates straight last, rigid sole of Cosyfoot surgical. Will not buckle or warp in splint.

## These corrective pre-walkers will help you and your patients

Big promise? Maybe. But here's why I think it's safe to say this new line of high-grade but *moderately* priced corrective pre-walkers offers you an opportunity. You can prescribe them with confidence and know your patients will not be overcharged.

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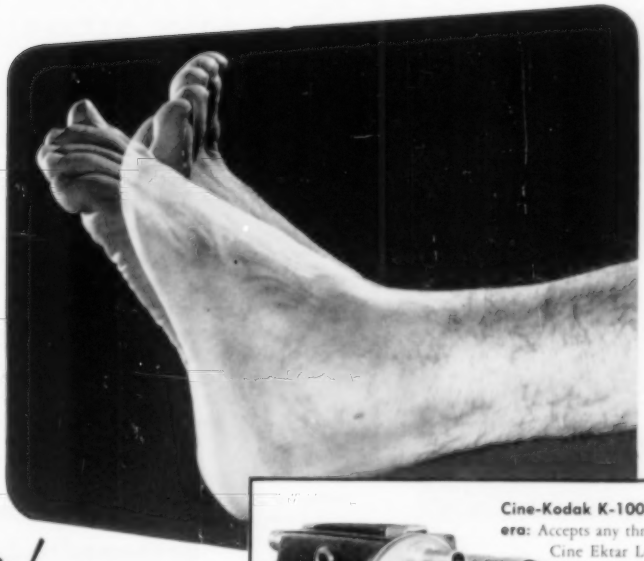

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# *Which* 16mm Kodak Movie Maker?

YOU'RE watching motion pictures of an orthopedic procedure. You marvel as the film runs on—needle-sharp—smooth—the colors crisp and clear. A surgeon friend of yours made it. You know he used a 16mm Kodak motion-picture camera. But which one? The Cine-Kodak Royal Magazine Camera? The Cine-Kodak K-100? Or the Cine-Kodak Special II?

***Actually, he could have used any one of the three. All are capable of magnificent results.***

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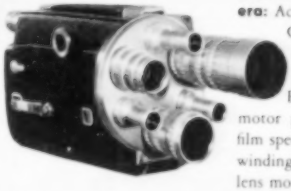
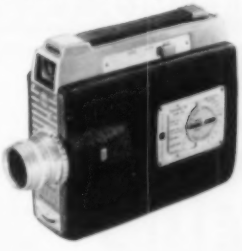
*Prices include Federal Tax where applicable and are subject to change without notice.*

**EASTMAN KODAK COMPANY**
**Medical Division, Rochester 4, N. Y.**

*Serving medical progress through Photography and Radiography*



**Cine-Kodak K-100 Turret Camera:** Accepts any three fine Kodak Cine Ektar Lenses—15mm to 152mm—combined with matching viewfinders. Powerful pre-stressed spring motor produces steady, accurate film speed—up to 40 feet with one winding. Priced from $315 (single lens model from $279).



**Cine-Kodak Royal Magazine Camera:** The convenience of magazine loading plus the excellence of Kodak Cine Ektar Lens, 25mm *f*/1.9. Choice of speeds; optical finder; pin-point focusing; easy adaptability to Kodak movie aids. Price, $179.50.

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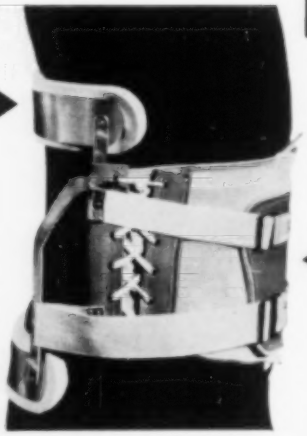
# WILLIAMS LUMBO-SACRAL FLEXION BRACE

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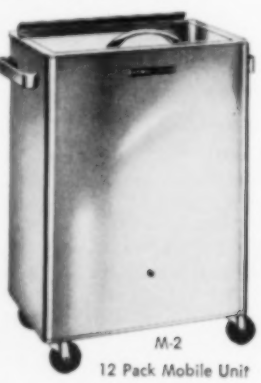

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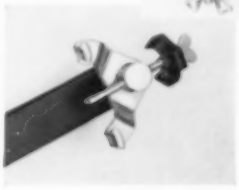
**DETACHABLE — DENIS BROWNE TYPE**

Orthopedic surgeons are even more enthusiastic about the new, improved Fillauer Night Splint. This versatile splint affords decided advancements for treating club feet, positional deformities, tibial torsions, flat feet, congenital hip dislocations, and any other deformities that are actively corrected by incessant kicking. Use of the Fillauer Splint minimizes the necessity of manipulations, plaster, tenotomies and anesthetics.



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1 Jackson, Ruth: The Cervical Syndrome, Clinical Orthopaedics No. 5, 138-148, 1955.

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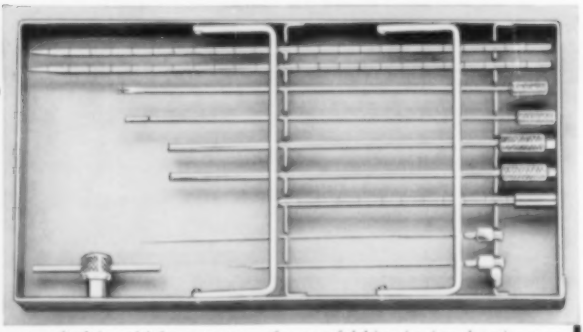
## VERTEBRAL-BODY BIOPSY

*by Frederick S. Craig, M.D.*
*New York*



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**REFERENCE:** The Journal of Bone & Joint Surgery, Volume 33-A, No. 1; page 93 et al., January, 1956. As described in Armamentarium, Vol. II, No. VI.

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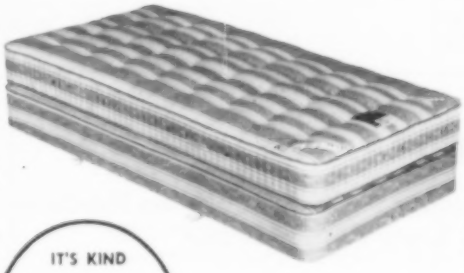

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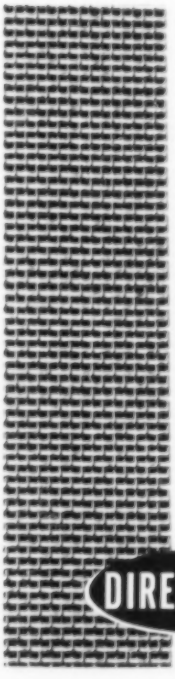

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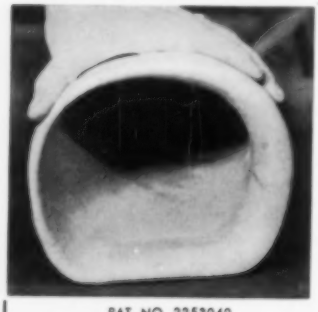

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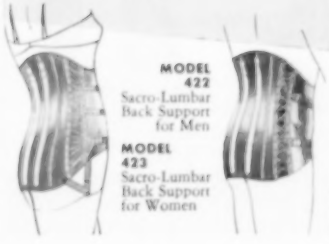

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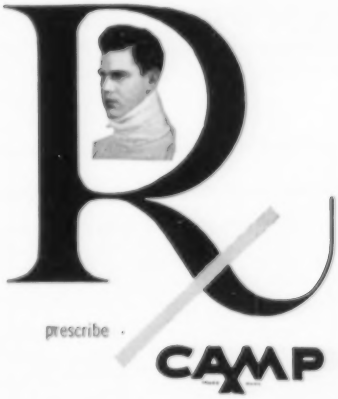

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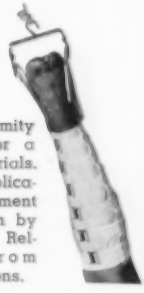

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*1903–1904:* Vol. I, Nos. 1, 2, 3, and 4; August, November 1903; February, May 1904.
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*1947:* Vol. 29 (Old Series Vol. XLV), Nos. 1, 2, and 3; January, April, and July.
*1948:* Vol. 30-A, No. 1; January.

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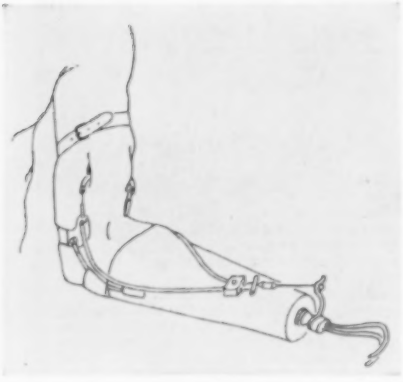

FIG. 1. Below-elbow cineplastic prosthesis with cables and terminal device fitted.

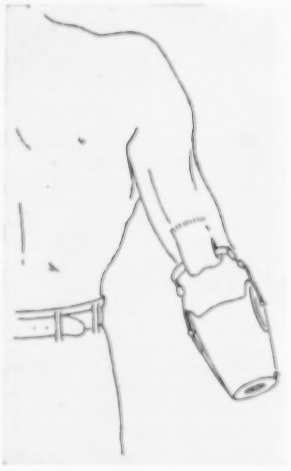

FIG. 2. Showing below-elbow prosthesis on stump with muscle tunnel pin in place.

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